

**CONVERGENCE:**  
Transdisciplinary Knowledge  
& Approaches to Education  
and Public Health

**Editors**  
Atila Ertas  
Basarab Nicolescu  
Sarah J. Gehlert

## **Dedicated to:**

Our good friend Bob Block for his endless support of ATLAS activities. We have had the honor of working with Bob over the past 20 years. It has been, and continues to be our honor and privilege to know Bob.



# **Convergence: Transdisciplinary Knowledge & Approaches to Education and Public Health**

*Editors*

**Atila Ertas**

**Basarab Nicolescu**

**Sarah J. Gehlert**

*The Academy of Transdisciplinary Learning & Advanced Studies*

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## Preface

This book represents the culmination of a series of interactions among a diverse group of scholars, policy makers, and entrepreneurs from around the world with a shared interest in transdisciplinary science and its implications for modern life. This volume focuses specifically on the implications of transdisciplinary science for education and public health. It is organized into three sections: transdisciplinary knowledge, transdisciplinary knowledge in public health, and transdisciplinary knowledge in education.

The volume's first six chapters address the future of transdisciplinary knowledge, the philosophical views underlying Paul Otlet's *Twin Utopias*, transdisciplinary thinking and skills, the utility of transdisciplinary knowledge for sustainable development, and qualitative marketing and neuroscience.

The second section of the volume deals with the implications of transdisciplinarity in public health. Two chapters provide guidance on training emerging scholars in transdisciplinary team-based cancer research and assessing the functioning of transdisciplinary research teams and use that knowledge to improve their functioning. A third chapter uses a systems dynamic methodological approach to addressing global public health in the area of cancer. Chapter four and five apply transdisciplinary science to the public health problems of cystic fibrosis and E. coli.

The volume's third section is dedicated to the application of transdisciplinary knowledge in education. It includes chapters on self-knowledge in transdisciplinary education, project-based education to solve complex problems using team, transdisciplinary pedagogy in the classroom, specific transdisciplinary science methods in education, and applying transdisciplinary knowledge to robotics education and research, and applications of transdisciplinary team-based education for sustainable development and for education in China.

The editors are grateful to those who contributed chapters to their book and to the Academy of Transdisciplinary Learning and Advanced Studies (ATLAS) for providing support to all the book's publication.

**Atila Ertas**  
**Basarab Nicolescu**  
**Sarah Gehlert**

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# CHAPTER **1**

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## Technological Singularity – The Dark Side

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*The technological singularity is defined as a hypothetical event in which artificial intelligence would be capable of recursive self-improvement or of autonomously building smarter and more powerful machines than itself, up to the point of an “intelligence explosion”, that yields an intelligence surpassing all current human control or understanding. We review the different opinions expressed around this idea and around the idea of transhumanism. We also analyze the phenomenon of panterrorism and the theme of the anthropocene. I formulate the hypothesis that the transdisciplinary interaction of philosophy and spirituality with other sciences, exact and human, is the privileged means of resistance to the new barbarism. I call “transdisciplinary philosophy” the philosophy which integrates the transdisciplinary methodology.*

### 1.1 Technological Singularity

The technological singularity is defined as a hypothetical event in which artificial intelligence would be capable of recursive self-improvement or of autonomously building smarter and more powerful machines than itself, up to the point of an intelligence explosion, that yields an intelligence surpassing all current human control or understanding. Because the capabilities of such superintelligence may be impossible for humans to comprehend, the technological singularity is the point beyond which events may become unpredictable. *One speaks about an essential singularity in the history of the human race beyond which human affairs, as we know them, could not continue.*<sup>1</sup>

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<sup>1</sup>Max More and Natacha Vita-More (Ed.). (2013). *The Transhumanist Reader - classical and contemporary essays on the science, technology, and philosophy of the human future*. Wiley-Blackwell, John Wiley & Sons, Inc, West Sussex, 2013.

Nicolas de Condorcet (1743-1794), the 18th-century French mathematician, philosopher, and revolutionary, is commonly credited for being one of the earliest persons to contend the existence of a singularity. In his 1794 *Sketch for a Historical Picture of the Progress of the Human Mind*, Condorcet states: “Nature has set no term to the perfection of human faculties; that the perfectibility of man is truly indefinite; and that the progress of this perfectibility, from now onwards independent of any power that might wish to halt it, has no other limit than the duration of the globe upon which nature has cast us.”

The term “technological singularity” was originally coined by the mathematician, computer scientist and science fiction author Vernor Vinge, who argues that artificial intelligence, human biological enhancement, or brain-computer interfaces could be possible causes of the singularity. Futurist Ray Kurzweil predicts the singularity to occur around 2045 whereas Vinge predicts sometime around 2030.

Vinge predicted four ways the singularity could occur:

1. The development of computers which are “awake” and superhumanly intelligent.
2. Large computer networks (and their associated users) may “wake up” as a superhumanly intelligent entity.
3. Computer/human interfaces may become so intimate that users may reasonably be considered superhumanly intelligent.
4. Biological science may find ways to improve upon the natural human intellect.

The basic idea is that although technological progress has been accelerating, it has been limited by the basic intelligence of the human brain, which has not changed significantly for millennia. Many writers tie the singularity to observations of exponential growth in various technologies, using such observations as a basis for predicting that the singularity is likely to happen sometime within our century.

Between 1986 and 2007, machines’ application-specific capacity to compute information has roughly doubled every 14 months; the capacity of the world’s general-purpose computers has doubled every 18 months; the global telecommunication capacity doubled every 34 months; and the world’s storage capacity doubled every 40 months. Like other authors, though, Kurzweil reserves the term “singularity” for a rapid increase in intelligence (as opposed to other technologies), writing for example that “The Singularity will allow us to transcend these limitations of our biological bodies and brains ... There will be no post-Singularity distinction, between human and machine”. He believes that the “design of the human brain, while not simple, is nonetheless a billion times simpler than it appears, due to massive redundancy”. He defines his predicted date of the singularity in terms of when he expects computer-based intelligences to significantly exceed the total sum of human brainpower. Kurzweil’s analysis of history concludes that technological progress follows a

pattern of exponential growth, following what he calls the “Law of Accelerating Returns”. Whenever technology approaches a barrier, Kurzweil writes, new technologies will surmount it.

In 2009, Kurzweil and Peter Diamandis announced the establishment of “Singularity University”, whose stated mission is “to educate, inspire and empower leaders to apply exponential technologies to address humanity’s grand challenges.” Funded by Google, Autodesk, ePlanet Ventures, and a group of technology industry leaders, Singularity University is based at NASA’s Ames Research Center in Mountain View, California.

In his 2005 book, *The Singularity is Near*, Kurzweil suggests that medical advances would allow people to protect their bodies from the effects of aging, making the life expectancy limitless. Kurzweil argues that the technological advances in medicine would allow us to continuously repair and replace defective components in our bodies, prolonging life to an undetermined age. Kurzweil further buttresses his argument by discussing current bioengineering advances. Kurzweil analyzed Somatic Gene Therapy (SGT), which is where scientists attempt to infect patients with modified viruses with the goal of altering the DNA in cells that lead to degenerative diseases and aging. Celera Genomics, a company focused on creating genetic sequencing technology, has already fulfilled the task of creating synthetic viruses with specific genetic information. The next step would be to apply this technology to gene therapy. Kurzweil’s point is that SGT provides the best example of how immortality is achievable by replacing our DNA with synthesized genes.

Computer scientist, Jaron Lanier, writes, “The Singularity [involves] people dying in the flesh and being uploaded into a computer and remaining conscious”. The essence of Lanier’s argument is that in order to keep living, even after death, we would need to abandon our physical bodies and have our minds programmed into a virtual reality.

Strong artificial intelligence can also be idealized as “a matter of faith”, and Ray Kurzweil thinks that the creation of a deity may be the possible outcome of the singularity.

The huge literature around the concept of the technological singularity puts the accent on the bright, attractive and utopian side of technology. In my talk, I choose to speak about its dark side.

From the numerous books, articles and Internet documents, I conclude that all this talking about “the technological singularity” is not rigorous. Science-fiction is not science and wishful thinking is not a serious thinking. In fact, the technological singularity is not a singularity in a mathematical meaning of this word. Exponential behavior does not mean singularity. All that, in my view, appears to be an excuse to dissimulate the basic ideology behind all that: the advent of *transhumans*. “Singularity” is used like a metaphor to suggest the jump from humans to transhumans. In another words, the technological singularity is the basic ground of what is called *transhumanism*.

Let me make, based upon the transdisciplinary approach, some short considerations about transhumanism.

If the transhumanist project will be achieved, human beings will become increasingly more a machine and the machine will become increasingly more human. The international cultural and intellectual movement of transhumanism advocates the use of biotechnology to improve physical and mental characteristics of human beings. Aging and death are considered undesirable and should not be inevitable.

Natural selection is considered to be outdated and it is replaced by technological selection. The major project is to remove any transcendent force and replace it with man-machine with superhuman intelligence, master of his/her life. Transhumans, which some philosophers and ideologists call them, for obvious oratorical precautions, “improved humans” or “ameliorated humans”, will constitute a new, bio-technological species. Future society will be divided between “transhumans” and “old humans”. The old humans will inevitably be servants of the transhumans.

It is remarkable that Sigmund Freud predicted the emergence of transhumanism already in 1930, in his book *Das Unbehagen in der Kultur / Civilization and Its Discontents*. He spoke of the desire of human beings to be equal to God, becoming a *God-prosthesis*. This process is achieved thanks to the second nature of humans, the technological nature, allowing them to dominate the world.<sup>2</sup>

From my point of view, we live in a time of a new barbarism which might be characterized by three words: Transhumanism, Panterrorism and Anthropocene.

I introduce the neologism *panterrorism* - to describe a new form of terrorism, without any real connection with a religion. Its aim is to kill the other in order to impose its own power. On November 13th 2015 Paris was hit by blind force of hate. It was a massacre of innocents. What was intended was to kill a certain way of life, whose symbol is Paris. In this new form of terrorism, there is no a soldier in front of another soldier. There are only killers who blindly exterminate an anonymous mass. The panterrorism, more and more present on our planet, is replacing God with the human being. By killing the other, the desire of omnipotence reaches an unpredicted climax. The French philosopher Marcel Gauchet noted in a recent conference that jihadism is a disconcerting phenomenon. Jihadism is, after the fall of the Nazi and Communist totalitarianism, a new form of totalitarianism that uses religion as a political project.<sup>3</sup> This new form of totalitarianism will inevitably use the new technologies – including 3D printing in order to produce arms and bombs, Internet of Things (IoT) in order to commit mass crimes, electronic chips implanted in the human body in order to dispose of a fabulous quantity of information, etc.

The technological singularity is blind to human values.

The word *anthropocene* is a neologism designating a new geological era,

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<sup>2</sup>Sigmund Freud, *Le malaise dans la culture*, Flammarion, Paris, 2010.

<sup>3</sup>Marcel Gauchet, “L’attraction fondamentaliste”, talk at the workshop “La psychanalyse et le fait religieux” organized by Association “Espace analytique”, Campus des Cordeliers, Paris, 19 March 2016.

characterized by the fact that the actions of human species become the dominant geophysical force of our planet as compared with natural geological forces. There is a danger today, for the first time in history, concerning the extinction of the entire human species.<sup>4</sup> The survival of the human species is, for a good number of scientists and philosophers, the most important issue of our time.

As the well known Australian climatologist Clive Hamilton writes in his book *Requiem for a Species*<sup>5</sup>, it is difficult to accept the idea that human beings can change the composition of Earth's atmosphere at a point of destroying their own civilization and also the human species. One can predict sea level rise of several meters during this century and the dissolution of the Arctic sea ice in one or two decades. One can even predict that the ice on the entire planet will disappear in several centuries, leading to rising sea levels by about 70 meters. Unexpected phenomena will occur: domestic animals will turn into wild animals and grown plants will disappear.<sup>6</sup> The consequences on the security of nations will be huge: waves of refugees from climate disadvantaged countries will emigrate to climate favored countries, which will cause unprecedented conflicts. International organizations are not prepared to face such a situation: they are not concerned with the security of the planet.

Paul Cruzen, Nobel Prize of Chemistry, proposed in 2006 to introduce aerosols into the atmosphere to reflect sunlight.<sup>7</sup> This suggestion has opened a strong research track, supported by prestigious institutions such as the US National Academy of Sciences and the Royal Society. The idea is to inject dioxide of sulfide into the stratosphere, in gaseous form, at an altitude of 10-50 km, forming in such a way of sulfate aerosol, particles that can reflect sunlight.<sup>8</sup> Paul Cruzen remarks in passing that the diurnal sky will become permanently white, a grim perspective on the aesthetic level. It is amazing that scientists of the stature of Edward Teller (co-founder and director of Lawrence Livermore National Laboratory in San Francisco) and Lowell Wood (researcher at the same laboratory and influential scholar at Pentagon) are among the staunch followers of this technological solution. With a huge vanity Lowell Wood said in all innocence: "We turned all the surrounding environments. Why do not we do the same with our planet?", an assertion which is, in fact, a transhumanist assertion.

From my point of view, in agreement with Clive Hamilton, it is not technology that will save our species, but a radical change of our vision of Reality.

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<sup>4</sup>See, for example, Bruno Latour, "L'Anthropocène et la destruction de l'image du Globe", in Emilie Hache (Ed.), *De l'univers clos au monde infini*, Éditions Dehors, Paris, 2014, p. 27-54.

<sup>5</sup>Clive Hamilton, *Requiem pour l'espèce humaine - Faire face à la réalité du changement climatique*, Presses de la Fondation Nationale des Sciences Politiques, Paris, 2013, translation in French by Françoise Gicquel and Jacques Treiner. Original edition: Clive Hamilton, *Requiem for a Species – Why We Resist the Truth about Climate Change*, London, Earthscan, 2010.

<sup>6</sup>*Idem*, p. 44.

<sup>7</sup>Paul Cruzen, (2006). Albedo Enhancement by Stratospheric Sulphur Injections: A Contribution to Resolve a Policy Dilemma. *Climatic Change* 77(3-4), 211-220.

<sup>8</sup>Clive Hamilton, (2013). *Requiem for a Species*, op. cit., p. 198.

It is evident that to meet this triple threat – transhumanism, panterrorism, and anthropocene, it is necessary to develop a strong, rigorous, universal and visionary thinking. Just humanistic claims are totally inefficient.

In this talk, I want to formulate the hypothesis that the transdisciplinary interaction of philosophy and spirituality with other sciences, exact and human, is the privileged means of resistance to the new barbarism. I call *transdisciplinary philosophy* the philosophy which integrates the transdisciplinary methodology.

There is a big spiritual poverty present on our Earth. It manifests as fear, violence, hate and dogmatism. In a world with more than 8000 academic disciplines, more than 10000 religions and religious movements and more than 6000 tongues, it is difficult to dream about mutual understanding and peace. There is a need for a new spirituality, conciliating technoscience and wisdom.

The first motivation for a new spirituality is technoscience, associated with fabulous economic power, which is simply incompatible with present spiritualities. It drives a hugely irrational force of efficiency for efficiency's sake: everything which can be done will be done, for the worst or the best. The second motivation for a new spirituality is the difficulty of the dialogue between different spiritualities, which often appear as antagonistic, as one can testify to in our everyday life.

Simply put, we need to find *a spiritual dimension of democracy*. Social and political life goes well beyond academic disciplines, but they are based upon the knowledge generated by them.

*Homo religiosus* probably existed from the beginnings of the human species, at the moment when the human being tried to understand the meaning of our life. The *sacred* is our natural realm. We tried to capture the unseen from our observation of the visible world. Our language is that of the imaginary, trying to penetrate higher levels of Reality - parables, symbols, myths, legends, revelation.

*Homo economicus* is a creation of modernity. We believe only in what is seen, observed, measured. The *profane* is our natural realm. Our language is that of just one level of Reality, accessible through the analytic mind – hard and soft sciences, technology, theories and ideologies, mathematics, informatics.

The only way to avoid the dead end of homo religiosus vs. homo economicus debate is to adopt *transdisciplinary hermeneutics*.<sup>9</sup> Transdisciplinary hermeneutics is a natural outcome of transdisciplinary methodology.

In this context, I want to recall a crucial feature of transdisciplinarity – the Hidden Third – that I introduced in my work.<sup>10</sup>

The zone of non-resistance, in between and beyond levels of Reality, plays the role of a *third* between the Subject and the Object, an Interaction term

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<sup>9</sup>Nicolescu, B. (2007). Transdisciplinarity as Methodological Framework for Going beyond the Science and Religion Debate. *Transdisciplinarity in Science and Religion*, 2, 35-60.

<sup>10</sup>Nicolescu, B. (2014). *From Modernity to Cosmodernity - Science, Culture, and Spirituality*, State University of New York (SUNY) Press, New York, USA.

which allows the unification of the transdisciplinary Subject and the transdisciplinary Object while preserving their difference. This Interaction term is called the *Hidden Third*. The Subject and the Object are immersed in the Hidden Third.

The Hidden Third, in its relationship with the levels of Reality, is fundamental for the understanding of *unus mundus* described by cosmocernity. Reality is simultaneously a single and a multiple One. If one remains confined to the Hidden Third, then the unity is undifferentiated, symmetric, situated in the *non-time*. If one remains confined to the levels of Reality, there are only differences, asymmetries, located in time. To simultaneously consider the levels of Reality and the Hidden Third introduces a breaking in the symmetry of *unus mundus*. In fact, *the levels of Reality are generated precisely by this breaking of symmetry introduced by time*.

In the transdisciplinary approach, the Hidden Third appears as the source of knowledge but, in its turn, needs the Subject in order to know the world: the Subject, the Object and the Hidden Third are inter-related.

The human person appears as an interface between the Hidden Third and the world. The erasing of the Hidden Third in knowledge signifies a one-dimensional human being, reduced to its cells, neurons, quarks, elementary particles and electronic chips.

The Hidden Third between Subject and Object is rational but it denies any rationalization. Therefore, Reality is also *trans-rational*.

A new spirituality, free of dogmas, is already potentially present on our planet. There are exemplary signs and arguments for its birth, from quantum physics till theater, literature and art.<sup>10</sup> We are at the threshold of a true New Renaissance, which asks for a new, cosmocentric consciousness. But, paradoxically, the new Renaissance potentiality is overshadowed by the violence of the new barbarism, which is a new phase of the confrontation between homo economicus and homo religiosus.

Etymologically, the word “barbarian” means one who is a stranger, an alien, who belongs to an uncivilized world. In this context, new barbarism introduces a radical newness, for it means that the alien is not outside us but within us. We are our own barbarians. There is an *ontological barbarism* consisting in the desire to reduce everything to a single level of Reality, a *logic barbarism* consisting in the refusal of any other logic than that of the excluded third, and an *epistemological barbarism* consisting in the refusal of complexity, of the interconnection between different levels of Reality.

## 1.2 Conclusion

The three tentacles of the new barbarism – transhumanism, panterrorism, and anthropocene – is a result of this triple barbarism – ontological, logical and epistemological. They have in common the assassination attempt of the Hidden Third.

Therefore transdisciplinary philosophy, which gives a profound meaning to the Hidden Third, is the privileged means of resistance to the new barbarism and it could educate the young generations in the spirit of this resistance.

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## About the Author



**Professor Basarab Nicolescu**, is theoretical physicist at the Centre National de la Recherche Scientifique (CNRS), Paris, France. Professor at the Babes-Bolyai University, Cluj-Napoca, Romania. Member of the Romanian Academy. Professor Extraordinary at the School of Public Leadership, Stellenbosch University, South Africa. Founding member of ISSR. President-Founder of the International Center for Transdisciplinary Research and Studies (CIRET), a non-profit organization (165 members from 26 countries), which has a web site at : <http://ciret-transdisciplinarity.org/index.php>. Founder and Director of the Transdisciplinarity Series, Rocher Editions, Monaco, of the Romanians in Paris Series, Oxus Editions, Paris and of the Science and Religion Series, Curtea Veche, Bucharest (in collaboration with Magda Stavinschi). A specialist in the theory of elementary particles, Basarab Nicolescu is the author of 130 articles in leading international scientific journals, has made numerous contributions to science anthologies and participated in several dozen French radio and foreign multimedia documentaries on science. Basarab Nicolescu is a major advocate of the transdisciplinary reconciliation between Science and the Humanities. He published many articles on the role of science in the contemporary culture in journals in USA, France, Romania, Italy, United Kingdom, Brazil, Argentina and Japan. His books include :The Hidden Third, Quantum Prose, New York, 2016, From Modernity to Cosmodernity - Science, Culture, and Spirituality, State University of New York (SUNY) Press, New York, 2014, Manifesto of Transdisciplinarity, State University of New York (SUNY) Press, New York, 2002; Nous, la particule et le monde, Rocher, Monaco, 2002 (2nd edition) ; Science, Meaning and Evolution - The Cosmology of Jacob Boehme, Parabola Books, New York, 1991. He edited Transdisciplinarity -Theory and Practice, Hampton Press, Cresskill, New Jersey, 2008. A complete biobibliography of Dr. Basarab Nicolescu can be found on the page: <http://basarab-nicolescu.fr/>.

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# CHAPTER 2

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## Information and the Future of Transdisciplinarity

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*A Transdisciplinarity, in the conception of Basarab Nicolescu, places the human being at the center of its preoccupations. Participation in transdisciplinary research and practice thus is not simply an intellectual exercise but an ethical enterprise whose finality is the furthering of the common good. In this acceptance, a key role is played by a non-standard logic, Logic in Reality, which provides a grounding of ethical behavior in physical science. In this chapter, I argue that part of the ‘future’ of transdisciplinarity lies in the joint application, to problems of the common good, of its core theses together with recent perspectives from the science and philosophy of information. Information and informational processes, in the conception of Wu Kun, are transdisciplinary and can be seen to evolve according to the principles of Logic in Reality. Together these concepts constitute a theoretical approach to a Global Sustainable Information Society that is both rigorous and humanist.*

**Keywords:** Common good, information, logic, philosophy, science, society, transdisciplinarity.

### 2.1 Introduction

In today’s world, I believe that philosophy has a critical social function in contributing to some minimal practical improvement in the human condition. The investigation of theoretical transcendental ramifications of thought has its own value and should continue. However, philosophy should also in part justify its existence and claim on resources by making some contribution to correcting problems of society. My first task in supporting this concept is, therefore, to explain my idea of what is the most positive actual and potential aspect of society, namely, the common good.

### **2.1.1 What Has Happened to the Common Good?**

In speaking about the common good, one should first distinguish between three different major, albeit closely related aspects: one is the informational environment, defined by the revolution in the information and computation technologies (ICTs). The increase in the negative pervasive and invasive aspects as well as the positive aspects of the ICTs calls for new non-technical as well as technical approaches to managing them to serve human interests. The second is the natural global environment which, apart from some very local improvements, is undergoing massive and possibly irreversible degradation. The third is the local socio-economic environment in which individual human beings evolve.

Wolfgang Hofkirchner, in particular, has addressed the first aspect in his examination of the requirements for the development of a Global Sustainable Information Society (GSIS) [1]. Approaches to the second are if anything even more complex, since they involve, directly, the degree of individual and collective commitment to social responsibility, maintaining the global environment as part of an overall ethical attitude. This brings us, unavoidably, into the field of individual and social psychology. There is general agreement that the objective of new science and technology is to promote advances in human civilization, civilized behavior and well-being. However, the large literature devoted to describing the problems, for example [2] whose title is, literally, “Why technology won’t save us or the environment” does not propose many non-technical ways of approaching them. Thus what is new and requires the attention of philosophers and logicians is not technology – science and engineering per se. What is new is the ever-increasing space, material and mental, that is abusively occupied, in the local environment, by the artifacts of technologies and their misdirection to individual selfish goals.

François Flahault is a French philosopher without illusions about the current direction of society. In his recent book [3], whose title is that of this introductory section, he shows that social reciprocity and coexistence are the essential requirements for a satisfactory individual life, defining the real, non-economic “common good”. However, the necessary codification of the rights of individuals, in the Universal Declaration of Human Rights in the aftermath of World War II, is now interpreted in an overwhelming context of market-driven globalization of the new information and communications technologies (ICTs), leading to a drastic and inhuman devaluation of the common good. Unless logic and philosophy, in conjunction with science, address these issues, they will have failed to address the reality of our world.

No paper like this one could present a formula or method for the establishment of a ‘better’ society that would somehow be widely adopted. However, I consider that a more scientific description of the grounding of ethical human ethical behavior is not just an intellectual exercise but a moral obligation. The two related tools that I see as having become available for this task are transdisciplinarity and informational science and philosophy. A necessary component of both is the non-standard logic of transdisciplinarity originally

proposed by Lupasco [4] and up-dated by me and made available to English-language readers as Logic in Reality (LIR) [5]. In this view, part of the ‘future’ of transdisciplinarity lies in a synergetic relationship with information leading to a better understanding of physical and cognitive phenomena and their evolution in informational terms. Such a combined theory may support non-technical solutions to the problems of the emerging information society.

### 2.1.2 Outline of the Chapter

In the next Section 2, I provide the briefest possible overview of transdisciplinarity and its logic. I do the same in Section 3 for the philosophy and metaphilosophy of information and their relation with the former as the scientific basis for this chapter. In Section 4, I review and criticize a few technologically oriented approaches to the organization of knowledge directed at increased social responsibility. In Section 5, I discuss recent developments in non-technical theories in the areas of ethics and environmental and social responsibility. Section 6 describes in more detail the Hofkirchner concept of a Global Sustainable Information Society. I conclude that inclusion of a transdisciplinary, informational perspective in theoretical and practical approaches to both knowledge and social problems is a methodological necessity.

## 2.2 Transdisciplinarity

The emergence of the concept of transdisciplinarity, and the field of transdisciplinary studies has come in response not only to the proliferation of disciplines and the need to manage their practical applications, but to the crisis in the related philosophies of science and knowledge in general. Transdisciplinarity is not a new discipline but a philosophical movement which, through its non-standard logic of human experience and human intelligence, can provide a new approach to on-going problems and paradoxes of human thought, science and philosophy.

### 2.2.1 Transdisciplinarity Today

Since the publication in 2002 by Basarab Nicolescu of his *Manifesto of Transdisciplinarity* [6] and in 2008 of his compendium *Transdisciplinarity – Theory and Practice* [7], applications of transdisciplinarity in both areas have greatly increased. Organizational networks devoted to transdisciplinary research and publication such as *td-net* in Switzerland, The *ATLAS* [8] and *INIT* provide centralized sources of information and opportunities for exchange of ideas, correlating scientific capabilities with human individual and social needs.

The difficulty of capturing the complex concept of transdisciplinarity in a single definition is well-recognized. Nicolescu has recently summarized [9] the thinking behind three major forms of transdisciplinarity: theoretical transdisciplinarity, phenomenological transdisciplinarity, and experimental transdisci-

plularity. He gives examples of each which will not be repeated here. The three forms of transdisciplinarity are by no means totally separated or independent but overlap and inform one another.

In the most general way, one may say that the practice of transdisciplinarity consists in application of the theory and methodology of transdisciplinarity to 1) the understanding of the relations between specific disciplines; 2) the solving of specific practical problems and 3) the understanding of the relation of transdisciplinarity to structured human thought, philosophy, logic and epistemology. In this chapter, I will focus on the third area, in particular regarding the emerging science and philosophy of information as conceptual structures directed at similar objectives.

### **2.2.2 The Logic of Transdisciplinarity. Logic in Reality**

In previous papers, both Nicolescu and I have discussed the Logic of Transdisciplinarity, one of its ‘pillars’. We have showed its origin in the logic of the included third of Stéphane Lupasco, and I have also discussed in some detail my interpretation of the Lupasco system as a non-truth-functional, non-linguistic extension of logic to real systems (Logic in Reality; LIR).

I simply emphasize the point here, critical for the discussion of information and the future of transdisciplinarity, that both approaches include the emergence of new states through the principle of dynamic opposition, the dialectic and interactive relation between the dual elements of all real processes. The difference, very briefly, is that Nicolescu looks ‘upward’ toward the transcendental aspects of existence while LIR focuses on the explication of the evolution of complex real systems, such as those involved in information processes.

My view of transdisciplinarity and its relation to a logic is similar to the discussion by Roderick Lawrence in his paper “Transgression of Disciplinary Frontiers” [10]. In particular, he cites the statement by Thierry Ramadier that “the specificity of transdisciplinarity consists in simultaneously integrating two *contradictory* movements (emphasis mine) of disciplinary logic, that is, the fragmentation of knowledge and the relation between the “fragments”, in order to do research into the connections possible between the (forms of) knowledge produced”. These are the kinds of movements, including their connections to the fundamental physics of our world, which Logic in Reality can describe.

### **2.2.3 Complexity**

The reviewers of a previous version of this chapter suggested 1) that too many subjects were being dealt with and 2) that complexity, one of the pillars of transdisciplinarity, is not found in the real world but is a human agent-dependent concept. In my view, both points can be addressed by noting that if the concept of complexity is not taken an abstract mathematical entity, but a statement that all natural processes are constituted by multiple, co-evolving and partly retrograde sub-processes, then this multiplicity is not

mind-dependent. To the extent that reality involves the interactions involved in these processes, described by Logic in Reality, reference to a multiplicity of subjects to gain a new and adequate perspective on phenomena is almost inevitable.

One role of transdisciplinarity, then, is to provide a framework for the analysis of different complex process phenomena that enables constants in their components to be, at least, recognized. One example is the relation between a general tendency toward altruistic behavior and a predominantly progressive political orientation. The relations elite – stability:: people – change; elite – material values:: people – sensitivity to fundamentals [11] are obviously oversimplified, but their discussion would require reference to all the sciences from physics and cosmology to psychology. I return to foundational questions of ethics in Section 5.

### 2.2.4 “Cyber-Space-Time” and Cosmodernity

These two concepts are relevant because they refer to the direction in which Nicolescu has taken the acceptance of transdisciplinarity. In particular, “Cyber-Space-Time” (CST) was presented by Nicolescu [12] as a new level of reality. For Nicolescu, the source of CST is the quantum world, which is ruled solely by the non-classical logic of the included third. Causality in CST is causality in an open loop, ruling the man-computer interface, and the interface with other partners. “CST is neither deterministic nor indeterministic. It is the space of human choice. To the extent that CST permits the bringing into play of the notion of levels of reality and the logic of the included middle, it is potentially a trans-cultural, trans-national and trans-political space.”

Nicolescu recognized the emergence of CST as a consequence of the ICTs even before the explosion of the social media of that last few years. His view, however, emphasized only the positive characteristics of CST, by now familiar, of some kind of collective mind or intelligence. In his latest book [13], Nicolescu uses the term ‘cosmodernity’ to express the idea of a new era, founded on a new vision of the contemporary, transdisciplinary and transnational interaction between science, culture, spirituality, religion and society. Reality is plastic and people are active participants in the cosmos.

In my interpretation of the Lupasco logical system, somewhat greater emphasis is placed on the current evolution of dynamic physical and mental processes than the transcendental aspects of man’s existence. Not everyone has the same desire and/or capacity to rethink ‘everything’ and act in consequence within a transdisciplinary framework. One should not lose sight of the resistance and barriers to achievement of such a desirable result. As Nicolescu himself has said, transdisciplinarity is always accompanied by an anti-transdisciplinarity. There will always be selfish, ‘non-cooperators’, people who will place their own well-being or that of their group above the common good, and I see their existence as another instance of the basic dualities of the universe that are the basis of Logic in Reality.

This interpretation notwithstanding, given my basic agreement with the finality of transdisciplinarity, it was for me an exciting discovery to find a complement to transdisciplinarity in the science and philosophy of information. These insights into the ‘workings of the world’ in informational terms are the work of the Chinese philosopher and scientist Wu Kun.

## **2.3 The Philosophy and Metaphilosophy of Information**

### **2.3.1 The Philosophy of Information**

In parallel to the development of transdisciplinarity, the last decade has also seen major developments not only in the information and communications technologies, but in the science and philosophy of information. As I will show, recent theories of information science and philosophy have a close relation to transdisciplinarity.

Starting in 1980 from philosophical considerations of the essence of information, Wu Kun, working at the Jiaotong University in Xi’an, China, developed a Philosophy of Information (PI) that included information ontology, an informational theory of knowledge, evolution, value, an ‘informational thinking’, social information theory including a rigorous conceptual system for the natural properties of information and an interpretation of its biological significance, methodological aspects and social value. Wu Kun published more than 330 papers on the Philosophy of Information and related areas in Chinese, plus several books and a 14-volume monograph. A small fraction of this work began to be available in English only in 2010 in a monograph presented at an International Conference on the Foundations of Information Science in Xi’An (“The Basic Theory of the Philosophy of Information” (BTPI) [14]).

This work was completely independent of the concomitant development of a Philosophy of Information by Luciano Floridi [15], working at the University of Hertfordshire in the U.K. The differences in the two approaches are philosophical: Floridi’s theory is basically epistemological, seeing the operation of information from the perspective of the human observer-reasoner. The theory of Wu is ontological, better ontological-epistemological, without absolute separation between the domains. In this, again, Wu rejoins the basic conceptions of transdisciplinarity.

The basic insight of Kun Wu’s Philosophy of Information is that the concept of objective reality = objective existence is too poor to describe a world which is the sum of processes of production, reception, storage and processing of information. A proper new ontology and worldview is needed to describe the phenomenological characteristics of that existence. The approach of Wu to information was to start with existence constituted as objective and subjective from a standard phenomenological viewpoint. He then placed the critical terms of existence, objective and subjective, reality and unreality, and direct

and indirect in a framework in which each combination of terms defines a path leading to matter-energy on the one hand and information on the other.

The principles of LIR support Wu's resegmentation of the field of existence (the extant domain) [16]. LIR makes it "logical" to talk about interactive relations between objective and subjective, reality and unreality, internal and external, direct and indirect and so on, and it does not exclude a priori the existence of real contradictions. Wu's view of information as involving interactive processes is not new as such. What in my opinion needs to be emphasized is the way in which internal and external factors must be understood. These include the multi-level nature and characteristics of the actual and potential (virtual) interactions that mediate the construction and transformation of information in which they (the interactions) evolve logically and dialectically. A key methodological conclusion is that the Wu approach contributes to recovering dialectics as an appropriate strategy for philosophy and science, including social and political science.

### 2.3.2 The Metaphilosophy of Information. Phenomenology

In his *Metaphilosophy of Information*, Wu Kun positions information as a critical component of all disciplines, beyond the formal content specific to them. A summary of his views in English can be found in [17]. At the heart of Wu's theory is a necessarily alternative worldview that emphasizes its relational and process aspects completely in the spirit of Lupasco's (*toute est relation*; everything is relation). We move from a quantitative, "technological" conception of information to what may fairly be called a transdisciplinary one.

In the light of information theory, the weaknesses of modern philosophy, from Kant through Husserl become apparent. It is the existence of information, even more than, but in concordance with, *Logic in Reality*, that breaks the traditional absolute separation of subject and object. Although Husserl found a way of beginning to describe the reality of consciousness, his one-dimensional phenomenological reduction maintains, in another form, the disastrous (for human society) polarization of standard bivalent logics. From a Lupascian standpoint, Husserl's bracketing is thus fundamentally flawed as a hermeneutic process.

In place of standard phenomenology, Wu proposes an informational ontology in which we as humans have (self-evidently) access to "things-in-themselves". He emphasizes that his philosophy of information and logic in reality are not phenomenology because phenomenology is the subjective intent of interpreting the structure of the world. We live, however, also as indicated in the dialectics of Lupasco, by adhering to route on which "the natural noumenon's own movement explains the world". Articles in the major 1999 compendium, edited by Jean Petitot and Francisco Varela [18], *Naturalizing Phenomenology* fail to reach the minimum complexity required. The implications of this view for phenomenological transdisciplinarity are most interesting, but outside the scope of this chapter.

While standard functional and operational definitions of information have their role to play in practical applications, they fail to capture both the intrinsic dynamics of complex processes and the nature of information itself which is instantiated in them. Thus, in the understanding of knowledge and knowledge propagation, drastic modifications of points in standard epistemology have to be made, with consequences for the dynamics of the emergence of new entities and meaning, in the contradictorial relationship that is formalized in LIR.

Using an informational paradigm illuminates work such as that of Lakoff and Johnson [19] on “The Embodied Mind”, in which the physical and physiological structures of the mind and body interact in an informational complex. Many workers in transdisciplinarity refer to some such concept as a way of better describing mind-body interactions in a non-reductive manner. To talk about information at any but the lowest computational level requires attention to the entire objective dynamics and subjective idiosyncratic patterns, consistencies and inconsistencies, styles of the human actors involved in its generation and reception, its historical dimensions, and so on. Wu has called this informational complex, constituted by the complete set of all of the informational processes and interactions of an individual, past, present and potential as the “informosome”. Anticipating the concept of the informosome, in a prophetic insight in 1975, the complexity of the informational processes in which the individual is immersed was described by the Swiss philosopher and mathematician Ferdinand Gonseth [20] as part of his ‘open methodology’. “Experience shows that no information is received in a pure state but only via the intermediary of a certain repertory of signs, symbols, notions, ideas, etc.” The result for knowledge is that it is subject to the modalities of incompleteness, pattern and revisability. Gonseth called for a critical examination of these modalities as protection against the “intense flows of information” that tend to reach us without one.

Taking into consideration the complex informational properties of existence is a difficult task for science, but it is the more correct position from which to start. To quote Wu: “Informational activities have their origin not in the pure “life world” of an idealized subject, but in the objective world of their own interactive existence and evolution.” One must maintain in the forefront of one’s mind the synergy between the physical form and the informational form and the rules of their evolution to fully understand their unified relationship.

Lupasco provides the basic formalism for discussing the “intertwining” of internal and external, present and potential (or absent) awareness and interactions, the “subjective active and the objective passive”, ultimately of man and nature in their unity-in-duality noted by Hofkirchner [21]. Application of the philosophy of information thus brings out an ontological domain, which Wu has called that of indirect existence as part of total existence, something that is objective and complex, having meaning and value and thereby constituting the elusive thing-in-itself that does not require further empirical proof in the reductionist classical sense.

### 2.3.3 Transdisciplinarity and Informational Thinking

It is perhaps a first indication of an approaching maturity of the field of information that, based on the contribution of Wu Kun, one can talk about the metaphilosophy of (a theory of) information in a social context. One of the consequences of the comprehensive nature of such a metaphilosophy establishes the role of those involved in them in the social and ethical aspects of the informational components of existence.

The Metaphilosophy of Information requires attention to the informational aspects of complex processes as a methodological necessity, in a process that Wu calls Informational Thinking. Informational Thinking (IT), as conceived of by Wu [14], refers to a way of grasping and describing the essential characteristics and attributes of things by reference to the structure and dynamics of the information involved in their evolution, from their historical origins to future possibilities and probabilities. However, as noted, the doctrine of Wu, unlike that of Husserl, does not have to be “naturalized”, that is, brought into the domain of natural science. It is already there in what I claim is a transdisciplinary configuration. Wu discloses directly the mechanisms of the processes involved in an individual’s understanding at the level of the integrated object and subject, with internal and external interactions providing the necessary multi-level objective and subjective mediation.

In this sense, all of the cognitive issues addressed by Wu, especially informational values, valence and social evolution, have implied the use of Informational Thinking for their analysis. IT requires the abandonment of thinking in traditional, absolute material terms while retaining its original foundations. IT is basically a methodological concept that, via the definitions of carriers and codes of information, enables inferences to be made about the historical and potential or probable future states of an information system. IT dialectically unifies energy factors and informational factors, determinism and indeterminism, internal and external feedback processes, independence (autonomy) and interdependence. LIR provides the additional logical structure for the dialectic interpretation of such a unified approach, based on the impossibility of any total logical or physical separation between these dualities. In fact, Informational Thinking is the Metaphilosophy of Information in other terms.

To the extent that Informational Thinking requires the consideration of all the philosophical and scientific facets of information, we believe that we are close to a new scientific (and logical) paradigm in which Informational Thinking, as opposed to thinking in terms of entities, results in new interpretations of, among other things, traditional disciplines and their theories. Above all, we see the (meta-) philosophy and (meta-) logic of information outlined here as a contribution to revealing the essence of information as a natural process. In other words, by seeing the relations between the changes in values that take place in human informational activities and the forms of society, a more profound understanding of information is possible that could be a contribution to overall progress and sustainable development of human civilization. Information Science, Metaphilosophy, Metalogic and Thinking may thus fa-

cilitate what Wu calls for, namely, a change in the commitment to and the interpretation of the dynamic oppositions in all complex natural processes in informational terms. This is thus a transdisciplinary doctrine *par excellence*.

Through the study of information as one of the most basic features of existence, and the formalization of informational activities, the Metaphilosophy of Information of Wu can and should change the way basic philosophical – metaphysical, epistemological and ontological – issues are discussed. The Philosophy of Information supported by the new extension of logic to the same processes that it discusses, could be a “comprehensive revolution in philosophy”, which I consider to be transdisciplinary in character.

Informational Thinking not only includes Systems Thinking as it is currently conceived but goes beyond it, much as transdisciplinarity goes beyond multi- and interdisciplinarity. In the spirit of LIR and this chapter, no invidious message of exclusion is intended here; as perspectives on knowledge, Systems Thinking and Informational Thinking too are related dialectically, and one can look, for example, at the interactive patterns of organizational structure and relational networks with a greater or lesser emphasis, depending on the objective, using the informational philosophical underpinning that Wu’s new illustrations of existence can provide. Nevertheless, it is Informational Thinking, including a logic of the included third, that is primitive and provides the framework for an improved understanding of systems.

In view of the rich space of possibilities for advances in philosophy and science offered by the concepts we have defined of Information Thinking, I hope that it may be possible to move the focus of debate away from the details of the formal, mathematical conceptions of information toward a more holistically natural, human and social approach. Wu’s term - the “informational rescientification of science” - is not intended to exclude any less rigorous criteria for the physical and logical validity of current science but increases the required degree of scientific and ethical responsibility of its practitioners. We should realize, only, that standard conceptions of logic, systems and information are a priori inadequate for this purpose.

### **2.3.4 The Informational Stance**

Wu’s concept of Informational Thinking, like transdisciplinarity in the acceptance of Nicolescu, defines an attitude in which rigor, opening and tolerance are both scientific and moral necessities, augmented by the feeling for information as a constituent of existence from the lowest to highest levels and having value as a consequence.

Informational Thinking in fact further describes a stance, the Informational Stance, a philosophical position and attitude that is most appropriate for, and above all not separated nor isolated from, the emerging science and philosophy of information itself. The Informational Stance [22] is an attitude that requires attention to the informational aspects of complex processes as an ontology that goes beyond the empirical epistemological formulation of van Fraassen [23].

Transdisciplinarity supports a humanistic worldview that is similar to Wu's Informational Stance. I note, as originally formulated by Wu, the non-separability of metaphysics, epistemology, value theory and social issues; "we should have a metaphysical picture of the world to discipline scientific methodology, and science and education policy". The Informational Stance is an interactive process, in which the human individual or group is engaged morally and politically, as well as being an epistemic observer in the standard philosophical sense. In fact, consistent with my overall logical approach, it is not necessary to make absolute separations between an informational stance, thinking, philosophy and the ethical dimension. It is rather an integrated or integrating position with alternating focus. The right integrative property includes complexity, because the origin of the basic emergent character of complexity requires only the prior multiplicity of difference and identity. Of course, emergence occurs not only at the integrative level, but also at the partial level, when the informational dimension is introduced, producing the holographic property of the general informational nature of entities, that is, the "informosome" referred to above.

In summary, the Philosophy of Information has transcended its origins in information and computation science and technology. It is not only that the Philosophy and Metaphilosophy of Information refer to the standard disciplines that makes them transdisciplinary but that they contain, like transdisciplinarity in general, what lies in, between and beyond the different conceptions of information – an attitude, a stance and an ethics.

These recent developments in the Philosophy of Information thus go far beyond the standard conceptions of philosophy. They establish the Philosophy of Information as a framework for the understanding of both philosophy and science in what may be termed a new knowledge paradigm directed toward the common good. In contrast even to the Philosophy of Information, the philosophy of technology [24], including information technology, remains underdeveloped outside the global concepts of Wu Kun discussed above. Discussing any one initiative in detail would be beyond the scope of this chapter, but it is useful to see how the problems of the common good are (or are not) formulated in all of them.

## 2.4 Organizing for Change

In this Section, I list a few recent approaches and initiatives directed toward a more effective organization of knowledge and action in the context of the information revolution. The participants include academic, industrial and political centers of competence and excellence as well as individuals. The multi- and interdisciplinary aspects of such technologically-oriented initiatives are accepted, almost without analysis, but the less obvious transdisciplinary implications for their possible successful implementation are rarely referred to explicitly.

### **2.4.1 TechNOfix**

The title of this sub-Section refers to a 2011 book by Michael and Joyce Huesemann [2] whose sub-title is *Why Technology won't Save us or The Environment*. As might be imagined, the book presents a detailed refutation of the myth that advanced technology alone will extricate us from “an ever increasing load of social, environmental and economic problems”. On the other hand, its methodology falls very rapidly into a kind of anti-scientific mode that represents the only suggestions the authors make for any minimal improvement in the commons. It is important to be explicit here: improvement in the common good, today, cannot be achieved without the new ICTs.

We thus have here another example of what is missing: some framework in which a conceptual repositioning of the ICTs can be achieved, going beyond the technology itself. Such a framework, in my view, can only be a transdisciplinary one that includes the philosophical and logical dimensions outlined here.

### **2.4.2 Tech FuturICT**

The concept behind the FuturICT initiative [25], in the framework of the European Union is clearly multi-disciplinary: “We think that integrating Information and Communications Technologies (ICTs), Complexity Science and the Social Sciences will create a paradigm shift, facilitating a symbiotic co-evolution of ICTs and society. The objective is also clear: it is to understand and manage complex, global, socially interactive systems, with a focus on sustainability and resilience. “Revealing the hidden laws and processes underlying societies probably constitutes the most pressing scientific grand challenge of our century and is equally important for the development of novel robust, trustworthy and adaptive information and communication technologies (ICTs) based on socially inspired paradigms.” In this formulation, the major output of new technologies would be further new technologies capable of exploring economic and social life and discovering options for a sustainable future.

This is fine as far as it goes, but in my view it does not go far enough. It is, exactly, a trans-disciplinary perspective that is missing, one that looks beyond the ‘power of information’ to the problems in using that power for which people are responsible. Even if this is understood implicitly, I believe it is part of the scientific perspective to refer to it explicitly

### **2.4.3 ICES**

ICES stands for International Center for Earth Simulation, recently established as a not-for-profit Foundation in Geneva, Switzerland [26]. In contrast to the previous conception, although it has as members many of the same centers of excellence as FuturICT, it will have the advantage when operative of being a physical entity. The scope and vision of ICES is the following:

Our vision is to create an *international resource centre* dedicated to simulating the dynamic Earth System as a Whole. We have set out to build a hub for *global innovation and public good*, using deep scientific understandings combined with advanced modeling, simulation and visualization technologies. To do this, ICES will install and continually upgrade one of the world's fastest supercomputers; improve the numerical models for the various dynamic natural subsystems of the planet; assimilate and synthesize data sets from regional and national research partners;

Thus, the sponsors of ICES recognize that at some time, the *output* of the computer or computers will have to be accepted by the society-at-large as a contribution to the common good, *explicitly*. At this stage of the process, non-technical, philosophical and psychological issues will have to be addressed [27]. It is at this stage, if it is reached, that both transdisciplinary and informational approaches may make a contribution to understanding and evaluating alternative courses of action.

#### 2.4.4 Crowdsourced Democracy

Disenchantment with the current system of two political parties in North America and Europe has suggested to some the use of the ICTs in the political arena. In fact, an 'Information Party' is in the process of being formed in the United States [28]. By definition, the objectives of 'crowdsourced democracy' should be the same as those of any democracy – the common good. However, the only thing that can be said at this time is that the platform of this party will be determined by the positions of the majority of its members, voting on-line.

The criteria for membership in the party are not yet clear; if it is open, these positions would simply reflect those of the prevailing majority, perhaps biased to somewhat higher educational and economic level than that of the average population. (Other attempts at 'electronic Town Halls' have been made that are simply part of the current 'blogosphere' and will not be discussed here.) It therefore remains to be seen what further social value, if any, an Information Party may generate in comparison with traditional parties.

### 2.5 The Common Good

A transdisciplinary philosophy and culture, which supports what is called here the common good, has been outlined by Nicolescu in [6]: a philosophy of the underlying unity of knowledge and a culture of openness and tolerance of opposing views combined with rigor in analysis. These views are restatements of basic ethical principles in other terms, but placing them in the framework of a methodology of transdisciplinarity helps to insure that they are discussed with the adequate rigor.

### 2.5.1 Social Responsibility and the ICTs

The most appropriate source of concepts for a better use of information science and technology for the common good should be information scientists themselves. I am convinced that negative attitudes toward technology as such are to be avoided, like all absolutist doctrines. As the information scientist and philosopher Gordana Dodic-Crnkovic puts it [29], “the question is not how to get rid of technology but how to get better technology that promotes human values and a sustainable society”. The target for dialogue is, then, the technologist to demonstrate to him or her that present technology is not socially sustainable and that improvement in social sustainability is both desirable and possible. Necessarily, it will be the engineering community that must constructively contribute to the sustainable development of society by designing and constructing devices that will better reflect our cognitive, social, emotional and informational needs.

But this is clearly only part of the answer. The process by which technology affects society and *vice versa* is never ending, but no single technical solution is final. Society as a living organism is in constant development, and the integration of any technical solution will lead to a change in the habits and behavior of society, for which the previous solution becomes inadequate. Society, to be considered here from the standpoint of these non-technical components, must be able to demonstrate the limitations of technical solutions suggest the need for non-technical ones and propose at least some reasonably rigorous conceptual framework for them as well. The prestige of information science suggests that it has the credibility to define necessarily transdisciplinary non-technical solutions and contexts that could be accepted by ‘technology’.

It is important, in such a discussion, to include and even focus on basic scientific concepts that have direct implications for the social value of technology. The ecologist Robert Ulanowicz has shown [30] that attempting to resolve society’s predicaments through the search for ever-increasing efficiency becomes equivocal in a world of limited resources in which entropy exists in two forms. Raising the efficiency of a given system beyond a critical point leads to catastrophes that tend only to restore the system to its original narrow range of operation.

### 2.5.2 Ethics and Environmental Responsibility

Another major area of the common good, as indicated in the Introduction, is the natural global environment the threats to which do not need to be repeated here. In the picture of that environment as a web of physical interactions which are also logical, ethical value is ascribed to the inanimate world by conscious humans as being that by which they are constituted, ‘down’ to the quarks of atoms or whatever might be at a still lower foundational level. In Floridi’s Philosophy of Information, value is ascribed to the informational aspect of existing entities [31]. The basic thesis of the Philosophy of Information is that all real processes, especially cognitive ones, are informational

in nature. To the extent one is talking in an ethical context about real people, individuals and groups, one therefore needs to talk explicitly about an informational psychology as well as an Informational Philosophy. This area is being currently addressed by Zong-Rong Li and his associates [32]. Li has suggested the term ‘Informationalism’ to capture the controlling function of informational existence in which information science and material science explain individual and social phenomena. This approach permits, among other things, a reformulation and interpretation of psychology and its history into a specifically Informational Psychology.

In my view, these two perspectives are compatible, valid ways of providing a scientific underpinning of norms for ethical behavior. In a sense, the electrons of which I am composed are an ultimate, essentially inaccessible ‘Other’, at the same time as being ‘Self’. Self-respect is the (linguistically) self-referential process of recognition of this relation and the basis for ‘Other-Respect’. Instead of life (biocentrism), one refers to the antagonistic dynamic relations between informational entities, without falling into pan-psychism. Note that in this analysis, it has been neither necessary nor desirable to insist on the physical-ontological to the exclusion of the informational-ontological. Both inform and confirm one another and the choice of emphasis and the movement from predominantly one to the other and back can follow the actualization-potentialization scheme that is codified in Logic in Reality. Some such an approach is necessary to counter the direct result of centuries of dogmatic thinking based on linguistic, bivalent logic that is in fact inapplicable to the complex, recursive dynamics of the real world.

As discussed above, the link between Informational Philosophy and transdisciplinarity is the logic of and in reality (LIR), which is, also, the logic of transdisciplinarity. A basic tenet of this logic is a respect for the other, as stated by Nicolescu in his Manifesto [6]. The other in the broadest sense is not only female vs. male in a male-dominated society and racial and ethnic minorities in general but human and non-human, that is, the total physical environment. In the LIR view of ethical behavior, the same metaphysical but also physical principle of dynamic opposition provides the basis for both 1) a generally applicable antagonistic psychological typology of responsible and irresponsible behavior toward the environment; and 2) the origin of environmental responsibility and in fact moral responsibility in general. Morality in the generally accepted sense of responsibility toward others as well as oneself and the environment is thus logically and ontologically grounded, as are other universal aspects of human behavior, both positive and negative. Environmental responsibility can be considered as scientifically valid and not dependent on transcendental assumptions that serve only to weaken its purport. Strategies to strengthen awareness of and positive response to environmental threats should thus emphasize common humanity and a common psychological structure across cultures as well as enlightened self-interest.

In other words, LIR and its non-separable categorial structure provides a scientific and normative rationale for the intuitive values of a universal human

morality; resource conservation; and the related issue of sustainable development which facilitates control of climate change. If survival in any society requires coming to terms with the existence of opposition and conflict, this is perhaps especially true in an Information Society dominated by the ICTs that offer only partial formal and technological solutions to environmental problems. As Herman Tavani [33] has shown, however, nothing has ‘happened’ to or in society that has changed the universal core moral human values of life, liberty and justice. The most applicable concept of morality is one which is not based solely on inherent virtue (virtue ethics), Kantian duty, social utility or social contract but involves aspects of all of them. Once the requirement of absolute non-physical cognitive individuality of human agents is lifted, the overlap or real ‘internalization’ of the other becomes obvious and the differences ones of perspective or description. By providing a more general and public, non-sectarian concept of the origin of morality, transdisciplinarity supports the necessary attitudes of openness and acceptance of the other’s position, and provides a basis for avoiding simplistic Manichean dogma, including the ideology of unlimited economic growth.

### **2.5.3 Toward a New Democratic System**

In the applications suggested by Wu Kun for his theory and philosophy of information, no specific comprehensive economic-political model is suggested, but he does call for a “new democratic system” that would permit maximization of the benefits from the new information technologies. It would include an informational perspective for studying social phenomena and provides a social information theory based on his concept of the essence of information in a social evolutionary context.

As shown by Wu [14], forms of human civilization can be differentiated according to their different ways of creating, processing, dissemination and development of information. Only human beings can create information. Human production and productivity are essentially only information production and information productivity, and models of the economy and market activity are informational models. The expanded role of social role of information is accompanied by the development of networks for its dissemination resulting in (slow) disappearance of centralized nation and global hegemony. In this process, information creation, processing and dissemination of the network approach becomes a technical prerequisite to building a new democratic society.

Human interests should be at the heart of any proposals for change in a society defined today by the evolution of its information processing modes in the scientific, economic and social domains. However, any theory or model of such changes cannot ignore (see my interpretation of the Lupasco logic above) the fundamental embodiment of contrary, anti-social and anti-civilizational forces in the society that make the “common struggle” for common good and implementation of the human values a struggle indeed. An “ideal” Informa-

tion Society would require, Wu suggests, the emergence of a diversified, non-authoritarian network involving a modern form of the atrophy of centralized natural systems. In any event, proper attention to the informational aspects of any politico-economic model is necessary, and would be the consequence of the Informational Thinking and Informational Stance described in preceding Section 3.

### 2.5.4 Transdisciplinarity and the Common Good

As an example of the relationship between transdisciplinarity and the common good, I note a recent *ATLAS* paper by Christian Pohl [34]. He first describes alternative combinations of four characteristic features of transdisciplinarity, namely (a) to relate to socially relevant issues, (b) to transcend and integrate disciplinary paradigms, (c) to do participatory research, and (d) to search for a unity of knowledge.

Pohl has established a concept of the function of a new transdisciplinarity network in Switzerland, the *td-net*, namely, to add additional features to the recent concentration on participatory research as the finality of transdisciplinarity. His concept “endeavors to frame, analyze, and process a socially relevant issue in such a way that the research project (1) grasps the complexity of the issue, (2) takes the diverse perspectives on the issue into account, (3) links abstract and case-specific knowledge, and (4) develops knowledge and practices that promote what is perceived to be the common good.” He then goes on to say that “the promotion of the common good – or, more generally speaking, the evaluative component of transdisciplinary research – is rarely stated explicitly in definitions of transdisciplinarity even though an evaluative component is inevitable in order to know what an improvement of the current situation might look like.” Later he says: “...one of the challenges for transdisciplinary researchers is to clarify underlying value systems by jointly developing the concrete meaning of, for example, sustainable development for the research project’s specific context”. The Logic of Transdisciplinarity, unlike standard logics, is not topic-neutral or morally neutral but founds an ethics. It is my hope that a transdisciplinary ethics, which has not yet received a minimum necessary codification, may develop from this work.

I agree with Pohl’s overall thesis as stated in these sentences, but I disagree with his choice of emphasis. In my opinion, the purport of the terms common good, peace, ethics and sustainability go beyond research and researchers in these fields toward the more general substantive meaning of the subjects of research, the necessity for their implementation and the barriers to that implementation. Accordingly, a next step, in my opinion, is to include, in transdisciplinarity practice, a greater explicit commitment toward the actual nature of the objects and processes under study.

I therefore discuss below some further issues in the area of ethics and the common good to which the transdisciplinary attitude may make a contribution. In my opinion, participating in “transdisciplinarity as a philosophical

movement” is not politically neutral, since any orientation toward a common good implies, more or less directly, some rather fundamental changes in social, political and economic values and priorities. As noted, it is perhaps in the area of information that a further functional role for the transdisciplinary attitude and transdisciplinary thinking is beginning to take shape.

The new social media enabled by the new ICTs are only partly and superficially effective in creating new ties, since the overwhelming emphasis is on the new capacities available to (some) individuals, seen as their rights, with very little about their duties, the other half of the dialectic of the common good. (The positive role of these media in pathological socio-political situations is not in question here.) Flahault shows that the concept of the common good is anterior to that of individual rights, but pious statements about the need to “work together” and “love one another” are inoperative. In order for the balance of power at the political level to further the common good, a new more scientific basis for the ties between individuals must be found than the market relations, the economic-social contract of individual consumption that relieves buyer and seller of all moral obligation.

Logic in Reality provides this: Two or more human individuals and their relations constitute interactive systems in the LIR categorial sense of non-separable subjects and objects, sharing in part one another’s characteristics. An individual is no more isolated logically, psychologically or morally than he or she is economically. Logic in Reality thus supports the relation between what was called pre-scientifically “natural law” and the conception of human society as necessary to human psychological existence, the real common good.

Neglect of the informational, and accordingly of the logical (in the above sense of the logic of the included third) and transdisciplinary aspects of thought may insure the purity of some academic research, but it also insures its irrelevance. In contrast, no scientific and technological work is without some redeeming actual or potential value to the community and hence has ethical entitlement to its share of limited resources. In this respect, the role of information and its technology in this respect has been clearly outlined by Rafael Capurro [35].

## **2.6 The Global Sustainable Information Society**

In the domain of information per se, my major source is the recent work in both information and the ICTs by Wolfgang Hofkirchner and his associates in Salzburg and (now) Vienna. Their concept that the study of the emerging theory of the information society is transdisciplinary, and in particular the new field of research in the Information and Communication Technologies (ICTs) and Society is a transdiscipline, was proposed in 2007 [36]. This definition is consistent with the functional definition of a transdiscipline in the basic charter of ATLAS [8].

The key aspects of a transdiscipline for Hofkirchner et al. are its scientific status and its potential societal function. As regards the scientific status

of the field, a transdiscipline does not mean a mere combination of existing disciplines but a transgression of their traditional borders and their transformation into something new with its own identity. Its terminology should overarch the terminologies of the single disciplines it departs from. A transdiscipline therefore is expected to bridge several gaps: the gap between the two cultures of (natural) science and social and human sciences as well as the gap between specialists and generalists as well as the gap between applied research and basic research. It is the result of a process that departs from mono- or multidisciplinary and transcends interdisciplinarity.

Hofkirchner argues that to the newly established field of ICTs-and-Society research must thus inhere transdisciplinary features, if it is to 1) be critical of current socio-economic developments; 2) aim for the establishment of a GSIS (Global Sustainable Information Society); 3) tackle the complex problems of society and technology; and 4) use social-scientific and technological, empirical and theoretical methods in a proper way.

Logic in Reality (LIR), supports this transdisciplinary view in general, involving integrative ICT assessment and design approaches that incorporate a normative view of technology and society. There is no place in LIR for value-free science; the practitioner is always involved logically with the material substrate of his science, whose dynamics and properties he partly shares. As clearly stated by Hofkirchner et al., a normative approach requires “doing justice” to what is normative and factual, actual and potential.

The term “transdiscipline” should thus be adopted in discussions of transdisciplinarity where it brings out better the issues under discussion. The conclusion of an on-line debate on this question in regard to ICTs-and-Society was generally favorable. Whether the use of the term conflicts with a definition of transdisciplinarity which is also supposed to be beyond all disciplines is for me a secondary question, perhaps best answered pragmatically by reference to transdisciplinary openness itself.

If it is the aim of an as-yet-to-be-developed science of and for the Information Society to help govern society when confronted with the well-known global challenges, it is the aims of transdisciplinary research to contribute to bringing about a Global Sustainable Information Society (GSIS). A GSIS can be defined in a normative way and technology (the ICTs) can be assessed according to how they facilitate society to live up to these values. This is in sharp contrast to either undertaking research solely for reasons of curiosity or being instrumental to whatever is demanded by parts of society. In contrast to the ideology of value-free science, here the normative criteria are laid down to which ICTs as well as society should be subject. A state of future society is envisioned in which these criteria are met.

## **2.7 Summary and Conclusions**

In summary, I have argued that one of the most if not the most important aspects of the concept of transdisciplinarity is its relation to the field of in-

formation and information science. The presentation of these concepts here is based on my belief that a new way of looking at thought and the traditional disciplines can make a contribution to a better anticipation of the future.

### **2.7.1 Transdisciplinarity and Its Logic**

The role and function of the logic of transdisciplinarity, originally proposed by Stéphane Lupasco and up-dated in some of my other publications as *Logic in Reality*, is to support, philosophically and scientifically, the transdisciplinary approach or attitude toward current issues in philosophy and science and to provide new insights into the qualitative, ethical aspects of the informational evolution of science and society. The presentation of these concepts here is based on my belief that a new way of looking at thought and the traditional disciplines can make a contribution to a better anticipation of the future.

It has become a commonplace to say that the future is contained in and/or anticipated by the present. To understand how this is the case is difficult if one tries to apply methods of analysis or inference based solely on the existence of actualized aspects, properties or parts of the phenomenon in question. *Logic in Reality*, as logic of transdisciplinarity, offers an organized way of looking at the current existence of future states in terms of potentialities.

### **2.7.2 The Philosophy of Information**

Following Wu Kun, I have shown that the Philosophy of Information is a metaphilosophy that includes various philosophies as its branches [17]. This Philosophy of Information also makes possible a new conception of nature, understanding, society and values and actively promotes the development of human information society, and a more civilized and democratic social polity, economic and cultural new order. His theories constitute part of a new transdisciplinary paradigm, in which information has a central role in the transformation of the society and its approach to knowledge and the classical separation of the academic disciplines.

In this chapter, I have argued that the major ‘future’ of transdisciplinarity and transdisciplinary studies may be in the construction, together with information studies, of a new concepts and contexts for favoring the common good and the development of a Globally Sustainable Information Society. To repeat, the inclusion of transdisciplinary and informational perspectives in scientific or philosophical work is not simply an intellectual exercise but a social and moral imperative.

I do not wish to imply that the combination of transdisciplinarity, Informational Thinking and *Logic in Reality* automatically provide a way of solving individual and social problems. However, by calling attention to their common dynamic structure and pattern of evolution, it suggests an attitude of openness and tolerance. New ideas and solutions may emerge as the (actual and potential) interactive transdisciplinary relations and oppositions between

different approaches are maintained in the forefront of discussion.

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Since our first meeting in 1999, Professor Basarab Nicolescu has been a constant source of energy and inspiration in support of my effort to make accessible, in English, the fundamental logical philosophy of Stéphane Lupasco and his own contributions to it. I had agreed with Nicolescu that this logic was the Logic of Transdisciplinarity, as discussed in 2005 at the 2nd International Conference of Transdisciplinarity in Brazil. In the next phase of my work, transdisciplinarity became to a certain extent secondary to establishing the legitimacy of Lupasco's Principle of Dynamic Opposition and the Logic of the Included Third (Logic in Reality; LIR) in current philosophical-metaphysical terms. However, as my interest then turned to the application of LIR in the most currently significant fields of systems science and information, the necessary functional role of transdisciplinarity and the transdisciplinary attitude, in the complex acceptance of Nicolescu, became again clearly "actualized". In this, I am also very grateful to Professors Wolfgang Hofkirchner in Vienna and Wu Kun in XiAn. Both have encouraged the application of LIR to their theories and philosophy of systems and information in which appear their own visions of transdisciplinarity. This paper is a first attempt to show not only the convergence of these two lines of thought but their common objective of contributing to the common good

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## About the Author



**Dr. Joseph E. Brenner** was born in Paris in 1934. In 1958, he earned a Ph.D. in Organic Chemistry from the University of Wisconsin. After a career in the chemical industry (Du Pont de Nemours International) in R&D and corporate development, he began collaboration with the International Center for Transdisciplinary Research (CIRET) in Paris, working with its President-Founder, Basarab Nicolescu. His major objective has been to make the logical system of the Franco-Romanian thinker Stéphane Lupasco (Bucharest, 1900 – Paris, 1988), a co-founder of CIRET, accessible to English-language readers. Key publications are his 2008 book, *Logic in Reality*, Springer, Dordrecht, and recent papers on applications of this logic to information and the philosophy of information. He was involved in the 2010 inception of the International Society for Information Studies, Vienna, Austria, of which he is the Vice-President for Inter- and Transdisciplinarity. Also in 2010 he was named an Associate Director of the International Center for the Philosophy of Information in Xi'An, China. Dr. Brenner is a member of the American Association for the Advancement of Science; and the Swiss Society for Logic and the Philosophy of Science.

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# CHAPTER **3**

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## Global Knowledge in the Global City According to Paul Otlet's Twin Utopias

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*This chapter discusses some of the philosophical tenets underlying Paul Otlet's work before and after World War I. A Belgian internationalist and documentalist, he anticipated the hyperlinked structure of today's world wide web and designed a universal documentation system to integrate all branches of knowledge. This comprehensive structure was meant to be the central focus to rule a world city representing a new world polity, which would in turn order international relations around a "scientific government".*

**Keywords:** City, cosmopolitan, global, science, Utopia.

### 3.1 Universal vs. Particular

Paul Otlet's ambition is undoubtedly impressive, but the means to achieve the twin objectives of his project are equally impressive: building the world city on the first hand, and grounding the knowledge of the world and human societies on the other. Three components were defined to this end. The first was a comprehensive coverage and classification of collected data, and their translation into the diverse forms of a universal scientific language to reflect the order of things and beings. Next comes the second, consisting in globalizing human societies as a consequence of globalized knowledge, to eventually generate a kind of "collective brain" which would enshrine science as well as and the feeling, will and memory of the world. The third system poses that the natural order of things is dominated by a supernatural, overhanging order.

As there is obviously no question of examining or commenting upon this

project in a few pages, we will deal with better known aspects of Otlet's two axes only: building the world city and systematizing knowledge through a documentary and classifying method. These are the first two components synthetically expressed in *Monde*, his opus magnum published in 1935.

## 3.2 The Historical Context

Whether considered from a purely international or taxonomic perspective, Otlet's work may appear to be anachronistic, especially when presented out of its historical and scientific context. It also reflects a utopian vision which can be explained in part as a rational response to a peculiar phase of what he considers to be a new world in the making, a form of international democracy or, to take a less ambiguous approach, a cosmopolitical ordering in which political institutions allow citizens to act, express opinions and be represented in the international field regardless of their geographical location (Archibugi 1995, [1]). However, the inter-war period does not provide "black and white" answers, being as it is a transitional phase fraught with tensions clearly appearing in Otlet's work when referring to the status of science and the political representation of social actors.

On the first point, in contrast with Edmond Husserl's observation that a sense of distrust of the role of science goes back to 1935 (Lecourt 1990, [2]), Otlet was still inspired by scientist views from the previous period: "... it is the entirety of human sciences that lead to knowing the Universe as a whole." (Otlet 1935, VII, my translation [5])

Second, the idealist version of conventional philosophical liberalism retakes the claims of such diverse thinkers as Kant, Locke, Hume or Rousseau that after the First World war a peaceful world could be rebuilt, designed as an international society based on multilateral institutions guaranteeing solidarity, civil liberties and democracy. The legal pacifism enshrined in international courts is quickly superseded by a utopian current targeted at a genuine *international government*. Leonard Woolf (Virginia's husband) is asked by the Fabian Society to write a report, released in 1916 under the heading *International Government* (Woolf 1916, [3]), one year after Otlet's publication of his own *Constitution mondiale de la Société des nations* ("World Constitution of the League of Nations", with the subtitle *Le nouveau droit des gens* ("the New Law of Nations") in 1917. Beyond any possible mutual influence, what is relevant here is the wide public and intellectual debate about the idea of international democracy surrounding the creation of the League of Nations as the first attempt to establish a world polity in the wake of World War I. In a way, this idea was a novelty in so far as democracy among equal states was far from being achieved even within states. Indeed, Utopia was for the first time stated in normative terms, predicating international democracy beyond the mere addition of national democracies and considering the very nature of international relations.

Generally, Otlet oscillates between the two ideal poles, political and scientific, with the World City being grounded on the scientific enterprise and vice versa, at least to some extent. In a way, his view diverged from Max Weber, who held in the same period that traditional knowledge legitimation processes (theological and cosmological) were receding to the full rationalization and intellectualization of social life, which in turn led to the “disenchantment of the world”, a Schillerian notion (*Weltentzauberung*) now associated with Max Weber’s name (Weber 1919, [4]). Whereas Weber was wise enough not to integrate social science into a social physics, Otlet insists that new prediction and planning means are available to improve social order, in line with the epistemological model of physics: “The recent rise of the so-called ‘technocracy’ gives sociological forecasting the opportunity to develop its full potential.” (Otlet, 1935 V, [5])

Fully indeed, in so far as the “sociological equation” considered by Otlet embraces all interactions between existing factors, to be integrated into a “world equation”. Logically, the basic reference is Adolphe Quételet (1796-1874), a Belgian mathematician, astronomer, naturalist and statistician, who composed a “social physics” along principles laid down by the Physiocrats, where the natural environment and the notion of *homme moyen* (“average man”) can be translated into statistical terms. In the same way as historical and economic cycles, the sociological equation can consequently account for constraints limiting human freedom and evolving from social contract to social legislation. The final destination of society and human creativity becomes determined, albeit in relative and statistical terms, within a constructed order.

In practical terms, Otlet’s initiatives focus on documentation and the building of one or more world cities. In 1901, Franz Kameny had already supported the idea of a world academy to gather “all cultural movements” covering sciences, literature and the arts, and a world centre for education (Grossi 2002, [6]). This led to the creation in 1909 of an international Bureau for Educational Documentation in Oostende, the first comparative institute of this kind (Speeckaert 1980, [7]). With the same universalist and educational aim in mind, he created with Nobel Peace Prize Henri La Fontaine the International Institute of Bibliography (IIB) in 1895, which sponsored the first World Congress of Universal Documentation, held in Paris in 1937, and was the parent organization of the Union of International Associations (UIA) created in Brussels in 1907. The IIB was also responsible for the development of the widely-used Universal Decimal Classification (UDC). The globalization of intellectual life was significantly supported by proliferating international non-governmental organisations, which were to coordinate and unify related bodies so as to gather in one single global system all data collected so far (Matterlart 1999, [8]). Similar congresses were held in Brussels in 1910 and 1913, and an international museum, a collective library and a universal bibliographical repertory containing 11 million cards classified by field and author were created.

The ultimate goal of such initiatives was, as Otlet said, “to unify the

civilised world as a whole in a common action with a view to achieving given aims of universal interest which individual states could not achieve, offering human kind the instruments it needed to gain greater power collectively, placing human activities under optimal conditions to develop fully. International organisations are meant to be linked with progress in human achievements and civilisation. Next to national civilisations and superimposed on these, there must be a world civilisation based on what the former share, so as to generate the spirit of a polycivilisation,” (UAI 1912, [9]). With this in mind, they proposed in 1920 a plan for an international intellectual labour organisation, a part of which led to the creation of the International Institute of Intellectual Cooperation located in Paris, which provided a permanent secretariat for the League of Nations International Committee on Intellectual Cooperation. Its aim was to promote international cultural/intellectual exchange between scientists, researchers, teachers, artists and other intellectuals.

The systematic collection and processing of data produced by the various analytical and mathematical tools available to researchers makes it possible to create a documentation system which could support sociological forecast: “In doing so, we can find natural resources to be used in forecast analyses. To this aim, a precondition is to possess all data. These data in the sociological area should consequently be registered in a more and more complete, detailed, and fast way.” Otlet’s continuing commitment, however, was to collect all data needed for global forecast, not only in the social field, but also in weather forecast, astronomy, geology, all the sciences which could “...bring examples of powerful inventories capable of inspiring and supporting social research,” (Otlet 1935, 425-426, [5]). The mechanical, systematized operations that announce the development of robotics allow him to think about sociological forecast and to ask : “Is it forbidden to imagine that society will have a set of adaptive institutions capable of carrying out balancing functions similar to automatic pilots in aircrafts?” (Otlet 1935, 429, [5]).

The influences that can be detected here, among others, are those of Saint-Simon, Fourier, the Fabian Society (Woolf 1916) and more schools which combine scientist and cosmopolitan approaches to what was presented as the establishment of a new world order. From a scientific and philosophical point of view, Otlet’s work is characterized by a number of conceptions which recall Kant’s rationalism, Leibniz’s quest for the philosophical basis of a universal human language – rather than Diderot’s *Encyclopédie* - and Novalis’s romantic project to integrate the whole of human knowledge. In Kantian style, Otlet’s method was aimed at grounding knowledge on immediate evidences, the careful and systematic review of available data referring to the various branches of knowledge. On the other hand, it shares with Kant’s humanism the progressive impetus that proclaims faith in reason and freedom and is committed to engage in a way of instructing the whole of mankind, inviting it to get free of this “minority condition”, of that “inability to use its own understanding without being controlled by another” (Kant 1795, [10]). Reason, will and sensitivity as faculties that belong to man according to Kant can be found in Otlet’s

writings, *mutatis mutandi*, as knowledge, action and feeling. Furthermore, he defines his method in the same way as Kant, halfway between a dogmatic rationalism à la Christian Wolff and an empirical scepticism à la Hume. However, the three systems that Otlet sees as the original conception of the world – positive analysis, the synthesis of the laws of thought and intuition, and a supernatural order, recall Wolff's dogmatic rationalism, especially with the tripartition of metaphysics into psychology (science of the soul), cosmology (science of the world) and theology (science of the divine).

### 3.3 The Scientific Utopia

Rational knowledge, as a prime component of a modern science that excludes any other dimension of thinking, goes back to the ideal model of Greek philosophy freed from contextual and cultural determinants to the point of severing universal science from its object, and represented by the “deified” thinker in Aristotle's cosmology, immune from doxa, myths and religion, where each type of substance from humans to primal elements has its own individual telos. The history of sciences has nevertheless shown that such a dichotomy has typically turned out to be deceptive, even more so as the cultural environment constantly biases the structuring of knowledge. In turn, science itself has never ceased to generate myths which often express a degree of mistrust of it (the Fall of Icarus, Faust, Frankenstein...). Thomas Kuhn would say here that conventional science can succeed in making progress only if there is a strong commitment by the relevant scientific community to their shared theoretical beliefs, values, instruments and techniques, and even metaphysics. Such biases imply that human means are finite, that there is no question of making scientists into preachers of truth. In the platonic tradition, this category of myths and representations speaks about the world through discursive and iconographical registers which have a multiplier effect. It is contemplative (*zoon logon echon*, living being endowed with speech and reason) rather than active, teaches rather than transforms the world (*homo faber*). It is the perfect language that Umberto Eco (1994, [11]) or Maurice Olender (1989, [12]) have admirably described, showing that scientific research in language continued to be impregnated with mythical elements until the early twentieth century, particularly with the myth of human origins.

In contrast with these primal myths, a second category appears, which resolutely engages with science, technology and what finally gives birth to contemporary technoscience. The universal science promoted by Otlet strongly interferes with technical inputs, with a science prone to becoming subordinated to technology, opening the way to mechanisation and automation, where humankind is bound to become an organic whole of peaceful and fruitful relationships between its units (Gon), (Otlet 1935, XI, [5]).

***Documentation or encyclopaedia?***

Otlet's ambition requires certain conditions to be fulfilled, one of them being the need to transcend cultural diversity, for which his approach to some extent goes beyond interdisciplinary inquiries to make transdisciplinary moves: "It is remarkable today that the primary source of new ideas and scientific breakthroughs does not come from traditionally recognized sciences, but from overlapping areas, a kind of scientific no-man's land," (Otlet 1935, 360, [5]). It therefore requires a unified science of society, whose many contradictions could be solved by an integration of knowledge and the establishment of an expected "scientific government" able to compensate for the global "hyper-separatism" he deplores, because documentation, he says, is the best means to establish the conditions under which stable and benevolent relationships between human beings can be fostered (Otlet 1935, 388 and 400, [5]). The underlying principles of these proposals refer to mixed traditions inspired by encyclopaedism, from Leibniz to Diderot and Novalis. Such approaches, like Diderot and d'Alembert's encyclopaedia, presupposed an overview of human questions, whereas Leibniz aimed for a universal communication system predicated on universal knowledge and Novalis aimed for the interdisciplinary interconnection of various realms of knowledge. To start with, Leibniz's view is particularly illuminating to understand universalisation in the field of knowledge, but also to conceive of communication beyond sociocultural contexts as well as scientists' subjectivity, not to mention his stance as a diplomat and a senior counselor at the Mainz and Hanover courts and, relatedly, his interest in peace building among European nations. Even though the universal science he grounded in the thesis that there is no mind-body interaction as such, but only a non-causal relationship of pre-established harmony or correspondence between mind and body, and his plan for a universal, artificial language to express concepts or ideas were doomed to fail, Leibniz's insight may look more plausible with hindsight, if we look at the the rise of computer science in the twentieth century. Utopian as it were, the Leibnizian vision actually ignored the arbitrary side of any classification – what Jorge Luis Borges would illustrate with his Chinese classification of animals (Borges 1993, [13]), which no Chinese encyclopaedia has ever described (In which it is written that 'animals are divided into: (a) belonging to the Emperor, (b) embalmed, (c) tame, (d) suckling pigs, (e) sirens, (f) fabulous, (g) stray dogs, (h) included in the present classification, (i) frenzied, (j) innumerable, (k) drawn with a very fine camel-hair brush, (l) etc.) However, it also responded to a practical need, leading to the proposed infinitesimal calculus to solve political and moral issues, or to reduce any discourse to a mere calculus on the condition that it is reformed so as to adopt a strict mathematical structure to adequately match concepts through the "universal characteristic" of language.

Otlet will retake the Leibnizian idea of a universal symbolic notation to this end. The Dewey Decimal Classification (DDC), or Dewey Decimal System (1873) adopted by the International Bibliographical Institute created in Brussels in 1895 to cover intellectual production in the whole word meets the

same needs. The most relevant feature for this discussion, however, is the ability to bring together all elements in a single interconnected whole with varying ways (orders) to proceed to each others, i.e. to create a genuine network structure, which departs from the deductive, linear sequence used by Descartes to describe the order of reasons. Cryptography, mapping, communication and documentation systems are all tools used to constitute a system of signs viewed by Marcelo Dascal (1978, [14]) as a genuine semiotic system, that is, what the Mundaneum was defined by Otlet: an idea, a method, a network, an institution and a “Summary of the whole, symbol of all symbols, prototype of all relevant things ordered and connected, classification of classifications, documentation of documentations, focus of focuses, university of universities,” (Otlet 1935, 453, [5]). The method applies a Leibnizian combinatorial view of concepts, based on an analysis into primitives, to which symbols or “characters” are then assigned, from which characters are formed for derivative concepts by means of combinations of the symbols. The bibliographical notation is a translation of it, with syntax and semantics. Relations are ruled by the Aritotelian logic, also rehabilitated by Leibniz as an infallible model for language rectitude to be emulated all along the seventeenth century (Kulstad & Carlin 2013, [15]).

This feature of universalism, which drew the attention of Henri Lafontaine more than Otlet's, is closely related to the social and scientific sides of their cooperation. Not surprisingly, the universal language is introduced as a logical and expected complement of railways, electrical telegraph, big exhibitions illustrating all scientific discoveries and industrial achievements of the time (Auroux 1997, 378, [15]). What distinguishes the two internationalists is only that Otlet was more concerned with a language (*langage*) able to convey the concepts laid down as universal, while La Fontaine was rather aware of the pragmatic dimension of communication, regardless of linguistic diversity, and the need for an international language (*langue*). Not surprisingly either, linguistic universalism appeared at the same time as Ludwik Lejzer Zamenhof's humanism in 1906, which created hillelism as the foundation for a universal religion taking account of all cultural traits and included the mystical Esperanto initiative.

However, it was particularly at the beginning of the last century that this particular universalism took its unique shape, as an ontology perfectly consistent with the ideas so expressed (Auroux 1997, 380-382 [15]), was to be replaced with an auxiliary international language better suited to practical uses. Even though the esperantist project initially supported by Otlet and La Fontaine – the latter was rapporteur of a delegation of eleven countries which submitted a draft resolution to the League of Nations' first Assembly in that same year - is still supported by some, the concept of universal language only survives in formal and computerised systems).

### **The Romantic Imprint**

One of the most highly innovative among romanticist works is Novalis's *Romantic Encyclopaedia*, which fully embodies the author's "Magical Idealism", a personal philosophy containing meditations on mankind and nature, the possible future development of our faculties of reason, imagination, and the senses, and the unification of the different sciences. One salient topic of romanticism is an ever-changing world torn apart by multiple contradictions, and this encyclopaedic project undoubtedly opens up new avenues into German romanticism and idealism in a post-Kantian perspective. In what he called his *unfinished notes for a universal science* (*Das Allgemeine Brouillon*) conceived in 1798-1799, Novalis reflects on numerous aspects of human culture, including philosophy, poetry, the natural sciences, the fine arts, mathematics, mineralogy, history and religion, and brings them all together into a "Romantic Encyclopaedia" or "Scientific Bible." In it, he intends to gather "the members long separated of total science." What should be noted here is, rather than Diderot and d'Alembert's "empirical aggregate" (d'Alembert 1991, 101 and 335, [17]), Novalis envisages a systematic project to deal with the oppositions unsolved by critical thought between subject and object, the ideal and real worlds. From philosophy to literature and science, he thinks of a system which unites knowledge, religion and aesthetics into a relative, plural universalism whose extreme modernity is a reflection on a universe which is both mobile and inexhaustible, characterised by both identity and contradiction, in an interdisciplinary perspective. As a whole, his system appears as an increased complexity of Leibniz's combinatorial model, inviting to think in several directions, to follow a mathematical sequence or a series of problems without any originating point (Schefer 2000, 15, [18]). It is a genuine opening to a dynamic and decentered universe, free from the Platonic ontology and Leibniz's pre-established harmony, which seems to foreshadow Deleuze's "nomad thinking" and the networking philosophy of which some aspects can also be found in Otlet's work.

Equally romantic is the reference to a cycle defined by a ternary structure, where the third term (art, religion or philosophy) is to synthesize and balance the first two terms (the real and the ideal, even if Otlet falls short of Novalis, who suggests, from another viewpoint, that this closed structure should be overcome to reach an open model without any reference point, "chaotic", "energized by a philosophy of the infinity" (Novalis 2000, 325, [19]). On the contrary, Otlet designs a kind of panopticon, "a single point wherefrom all world events could be observed, all individuals could realize that his conscience, his will, his feeling are but aspects of the great whole, the aspect suited to the synthesis of his own being, his personal case" (Otlet 1935, 385-386, [5]).

### **The Political Utopia**

Considering that Otlet appears to be Leibnizian with a touch of romanticism in the sphere of knowledge and its dissemination, the question is whether a

similar approach applies to his view of international relations. At first sight, his idea of a comprehensive restructuring to save humans from the scourge of what was a “total” war, not only military, economic and cultural, but waged also against civil populations. This may be compared to Leibniz’s comments in the decades that followed the Thirty Years War (1618–1648), before the Peace of Westphalia was signed with a view to allowing European peoples to better communicate and stemming the devastating power of conflicting theologies that had divided the continent. However, the comparison stops there, because Leibniz was never a pacifist and did not endorse the idea of a “perpetual peace”, which first came up during 18th century when abbé de Saint-Pierre was working as the negotiator for the Treaty of Utrecht, while Otlet remained a utopian in the international field as he was in his view of science. Even if it necessarily presupposes a rational, if not mathematical foundation, the Leibnizian “best of all possible worlds” quite suggests a *Realpolitik* (Leibniz 1715, 328-336, [20]), where the “world constitution” conceived by Otlet and Lafontaine is overtly cosmopolitical.

Additionally, the associated social model impresses with its platonic overtones, with a “scientific government” (Otlet 1935, 329, [5]) whose purpose and substance are not too different from the aristocratic government embodied in Plato’s regime ruled by a philosopher king, and whose contemporary figure may be the oligarchy of scientific and technocratic experts present in various fields of governmental decision making. So, the conception of a “total prediction” and “world equation” was to logically lead to this other side of Otlet’s utopia, the concept of world city which fulfilled the vision of a total centralization of international power and knowledge. He tried to reconcile this with the assumption that human freedom and creativity laid in controlling correlations between diverse activities. Despite these apparently conflicting assumptions, both approaches - social forecast and building a world city - were greatly stimulated by the many actions and reflections that supported endeavours toward world peace, the status of science and, as an increasingly pressing need, the architectonic design of societies in the most literal sense, notably of town and cities and the communication networks supplying every place. In this regard, Otlet admired the inventive genius of Le Corbusier (Courtiau 2003, [21]), who illustrated in his mind the concepts of what was unpredictable and unexpected, these “continuing, sudden outbursts of modern events, the powerful disruption in life, the disarray triggered by psychics such as inventors” (Otlet 1935, 418, [5]). The kind of city that resulted from their cooperation may seem filled with a sense of totality, present in similar utopias, opposed to any degree of freedom and creativeness. The progressive momentum - understood as the new avenues opened by science and social and societal advances - that prevails in urban planning in during the first half of the 20th century until 1960 gave rise to the International Congress for Modern Architecture (Congrès internationaux d’architecture moderne, CIAM), an influential association of modern architects and city planners united in a search for solutions to the problems of urban areas. Founded in 1928 by Le Corbusier

and Sigfried Giedion, CIAM served for several decades as the organizational centre of the modern movement in architecture and its alliance with technoscience. In their minds, the world city is one example of a paradoxical utopia combining imagination and social, political and economic issues, in a transition period involving critical reflection, reform projects or even revolutionary ideas (Courtiau 1987, [22]). In this context, the spatial model designed for a similar purpose by Otlet and Le Corbusier reminds us of the Renaissance upheavals, when Thomas More published the founding text of *Utopia* (1516) which criticized the society of that time, designed that “nowhere land”, the anti-society opposed to the former. The reference to *topoi*, as mentioned by Aristotle, is in fact one function of imagination to crystallise memory (Wunenburger 1997, [23]) is often made by Otlet to link sensory impressions to artificially visualise them in space in order to control the process. More’s utopia had admittedly no practical end, but Otlet’s is meant to be a practical achievement justified by the horror of WWI. This practical aim may explain the absolute, almost mythical character of model cities promoted in the Athens Charter (Charte d’Athènes), and consequently the charges of scientific terrorism brought against them by their opponents, who exposed the dogmatism displayed by some architects claiming, as argued by Le Corbusier, that “Experimental evidence is available, everything is being tested in scientific experiments” (Choay 2001, [24]).

The political side of this movement is in some ways a natural outgrowth of utopian developments, a recurring pattern since ancient Greece first linked myths to religious narrations providing collective truth in so-called pre-rational or traditional societies to later grant them their autonomy, so that myth became “a meaningful vector, without imposing a single truth, only if it is contemporaneous with a *logos*, a hermeneutic reason which will interpret in an unhindered, open way, according to a form of questioning,” (Wunenburger 2002, [25]). Western politics has been gradually nourished by such defeated myths, from the newly-gained autonomy of Greek cities up to the late development of modern democracies. Whether ingenuous or overoptimistic, Otlet’s plan is only a revival of this story. As early as the second half of the 18th century, Jacques Tenon (1788, [26]) endeavoured to incorporate the hospital into modern technology. Locating this institution within the cosmopolitan, humanist culture of his time, he saw it as a cumulative, collaborative, supranational effort of scientists, physicians, learned societies, governments, and even ordinary citizens. He referred to the medical institution as a “measure of the civilization of a people” and undertook the transition from the medieval to the modern hospital. Another example, from a more punitive point of view expressing the shared principles and scientific creed of utopians, is Jeremy Bentham’s *panopticon*, a penitentiary based upon an idea of his younger brother, who while working in Russia for Prince Potemkin, hit upon the “central inspection principle” which would facilitate the training and supervision of unskilled workers by experienced craftsmen. Bentham came to adapt this principle for his proposed prison, a circular building with the prisoners’ cells arranged around the outer wall and the central point dominated by an inspection tower. From this

building, the prison's inspector could look into the cells at any time and even speak with them, though the inmates themselves would never be able to see the inspector himself.

### **The Communication/Information Challenge**

In the early 19th century, a variety of critical models thrived, global and no longer fragmentary, from Owen's New Harmony city in Indiana to Etienne Cabet's French-based icarian colonies established as egalitarian communes in several American states, to Hygeia, a City of Health, by Benjamin Ward Richardson in England, and all those Karl Marx called the "utopian socialists" (Owen, Fourier, Cabet and their followers). Otlet's global plan would combine various aspects of them, from the hygienist component to the communication utopia. A common feature that appears in them, whether cognitive, global or focused on communication, is a trend to aggregate individual data within a centralized, if not totalitarian pattern, which threatens individual creativity and freedom in human communities. Followers of the Platonic city have consistently resorted to expressions of dogmatic knowledge, a monopoly of political power, censorship of human expression in its diversity, or for a significant part of it set them down on the side of digitization. However, the historical context of human representations has also held that *The Republic* and *Laws* present model cities more closely related to fairness in mystical communities than the standardization of minds in totalitarian states. Plato's city would be situated, as suggested by Jean-Jacques Wunenburger, "...between the ideal of Pythagorean brotherhoods and the blueprints for society as imagined by Christian utopias of the Renaissance" (Wunenburger 2002, 90, [25]). Later utopias, from Thomas More to today's contemporary varieties, are pre-arranged, closed communities in the fields of property, religion or sexual life which have little to do with current cosmopolitan projects. In this sense, Otlet's world city ultimately remains paradoxically trapped in a social ideology which, despite its progressive, modern ambition, reflects the basic concepts of its time closer to philosophical and political conservatism.

In some ways, today's political projects have lost good part of their original substance and initial impetus, to the point that even democracy has reached the point where it is threatened by all kinds of dogmatism, religious and economic as well as scientific and, on the other hand, by an implosion which could become, as suggested by Emmanuel Todd with reference to Plato, an oligarchy of the powerful and the experts (Todd 2002, [27]). True, other dimensions seem to figure on the horizon, emerging or projected from the collective brain and cyberculture, global civil society and universal jurisdiction, namely what is left in the end of a utopian imagination: building a global order based on more democratic international relations, a new world-wide covenant on man and the biosphere, or universal access to knowledge and information. If Otlet foresees the emergence of Teilhard de Chardin's omega point seen as node of ultimate synthesis and consciousness, Joël de Rosnay's global brain as the

worldwide network formed by all individuals together with the information and communication technologies, it usually keeps a partial, if not biased or literal, platonism or neo-platonism, Leibniz's *characteristica universalis* of the educational legacy of encyclopaedism. Documentation would allow science to gradually be severed from human mind and materialize the world of ideas, man would ultimately and instantaneously contemplate every side of the Universe through his technological tools (Otlet 1935, 390-391, [5]), which would reflect the Idea, this "ideal model of which the artist will make a copy in the physical world," (Wunenburger 1997, 117, [23]). This mimetic gesture is still present in a number of cyberworlds, sometimes in radicalized versions not significantly different from ideas implicit or explicit in Otlet's writings, pointing to a dynamic and hierarchical pattern toward a "collective brain" which would raise man to that "omniscient being, equivalent to God himself" (Otlet 1935, 358 and 390-391, [5]).

### 3.4 Conclusion

Like all utopias, the world city and the Mundaneum draw from history, while taking into account hopes for the future and occasionally carrying out effective projects. Plato, Leibniz, Kant and other thinkers unsurprisingly leave indelible marks, while contemporary intellectual schools celebrate the all-powerful science and embrace the illusion that they would lay down the rational foundation for a brave new communication world mounted into a cosmopolitical framework whose early signs had appeared in the first decades of the 19th century. Among its representations, the metaphor of a sphere (Otlet 1935, 385, 452 and XXV, [5]) is particularly revealing, when it solves in a few concepts the presence to the real world in all its breadth from a central point realises the full potential of being, a *panopticon* of sort which however contradicts the networking assumption usually ascribed to Otlet. Indeed, even as it was known in the 1920s and 1930s networking was a complex web of heterogeneous elements between chaos and hyperstructuring, order and disorder, which was rather reluctant to submit to a single regulator. As Umberto Eco (1972, 368-370, [28]) said some time ago, there is communication because we cannot see everything at a glance, or better still because the whole cannot possibly be seen at a glance. Networks are the setting for the confrontation between centering and decentering, the obliged passage rather than a heuristic instrument. Cyberworld experts say nothing other than that when they see communication tools as an empty place, a crossing point for the future, and not the foundation for a new social structure (Musso 2000, [29], Sfez 1992, [30]).

The social and political aspects of Otlet's views appear equally paradoxical, in so far as their aims are socially progressive and scientifically ambitious, the underlying concepts and implicit outline make them philosophically conservative. From Comte's "social physics" to Durkheim's essentialism, French views in social science focus their efforts mainly on improving social prediction and

restoring community relationships and social order through the development and implementation of authorities which would reach more certainty, control moral behaviours and in fact postpone social change. Similar views can be found with Tönnies, who opposes close personal relationships in “communities” and impersonal relationships in “societies”, or with Weber, who deplores the consequences of the increasing rationalisation of social life and the resulting “disenchantment of the world”, and particularly the weakening community ties characteristic of modernity (Bottomore 1964, [31]).

These features culminate in a “taxonomic vertigo” with Otlet, a striking example of the classification reason fully consistent with Leibniz and the encyclopaedist aim, the idea of a *deus ex machina*, the illumination under a mechanical system, which conserve the preconceived harmony of the Platonic ontology. In the spirit of Leibniz’s interest in Chinese ideograms, he looked for a universal, conceptual language which could become effectively international, sought a documentation synthesis which would generate an “intellectual machine”, a kind of duplication of human and social bodies covering varying figurative modes informed by concepts, mathematics and images, to ultimately reach a maximum abstraction accounting for knowledge, national democracies and global governance. Assuming that Otlet’s visionary project marks the dawning of contemporary communication technologies, its organicist bias cannot be considered as revolutionary; it also differs from the systemic and network thinking as conceived by Novalis, namely an open-ended, ever-changing universe with no single point of reference. The question remains as to whether modern societies can avoid this shifting nature, either expanding to a multicentric, deterritorialized space or withdrawing into an identitarian closure, the very thing we call premodern.

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# CHAPTER **4**

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## The Many Ways of Thinking: Transdisciplinary Skills

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*This chapter proposes that college curriculum include classes in multiple ways of thinking. It provides interesting historical and contemporary examples of thinking styles. When thinking about this presentation, it became clear to me that the same arguments used in favor of transdisciplinary (TD) education are applicable to learning multiple ways of thinking and should be an education mainstay.*

**Keywords:** thinking, transdisciplinary thinking, business thinking, thinking exercises, thinking exercises for the workplace, business critical thinking exercises, brain trainer, mental practice, scenario planning, transdisciplinary skills and role playing.

### 4.1 Introduction

Transdisciplinary (TD) Thinking is one of the most powerful TD skills. It should be taught to all students at every level, as a foundational part of their education. Learning to think in multiple ways will advantage every student. Thinking, along with its sister skills, memory and concentration, imagination, intuition, curiosity and inspiration provide the access to the caverns of our minds. Yet, there is precious little formal time spent on improving these TD skills. Organizing and structuring information (classification) and consciously deciding to think about a particular problem or opportunity also improves decision making.

## 4.2 U.S. Patent Office

On at least one occasion I told ATLAS the story of Charles H. Duell, who, in 1898, as head of the US Patent Office purportedly asked President McKinley to close the Patent Office because, “Everything that can be invented has been invented.” While researching for this presentation I discovered that far from wanting to close the Patent Office, Commissioner Duell was a proponent of growing technology.

Duell is quoted as saying, “In my opinion, all previous advances in the various lines of invention will appear totally insignificant when compared with those which the present century will witness. I almost wish that I might live my life over again to see the wonders which are at the threshold.” Duell was right.

The probable origin of the famous “Everything that can be invented has been invented”, may be found in a report to the US Congress in 1843 by an earlier Patent Office Commissioner, Henry Ellsworth. In his report, Ellsworth states, “The advancement of the arts, from year to year, taxes our credulity and seems to presage the arrival of that period when human improvement must end.” This quote was apparently misinterpreted and then miss attributed to Duell, who held the same Commissioner’s office in 1899.

So here we see two ways of thinking applied to the same set of facts. Ellsworth looked at human limitations and concluded that at some future time, humans would run out of creativity. Duell looked at human potential. He concluded that humans would continue to invent. How do we chose between these strong views?

While it is impossible to know the future, it is possible to influence the future. The job of the Patent Office Commissioner is a strategic one. It calls for forward thinking and the encouragement of human growth. The Patent Commissioner should think in positive long-term human trends. Doing so, will help to make them happen.

## 4.3 Many Ways of Thinking

It is clear that TD thinkers think differently than specialists, engineers think differently than lawyers, who think differently than doctors, who think differently than business people, who think differently than students, who think differently than professors, who think differently than Republicans, who think differently than Democrats, and on and on.

But it is a lot more complicated than that. We think differently in our personal lives than we do in our working lives. We think differently when we are young than we do when we are older. We think differently after our first cup of coffee in the morning, women and men think differently and so on. In fact, each of us has a unique thinking inventory or thinking style.

## 4.4 How We Think vs. What We Think

There is a difference between what we think and how we think. For example, we don't get to decide if it rain... but we do get to decide how to feel about the rain and what to do about the rain. You can get upset about the rain spoiling your plan for the day, you can use the time to read a good book or you can celebrate the rain as a gift of life.

The main purpose of this chapter is to encourage you to think about thinking and the ways thinking can be taught and learned. For example, students can be taught to think about their work from the perspective of an employee, a manager, an employer, an entrepreneur or intrepeneur or as a business partner or owner. How students will think about their work will be critical to their success.

Students can be taught to change their way of thinking as circumstances require. They can emphasize thinking in the short-term (get things done) or thinking in the long-term (get difficult things done) they can be taught when to be focused and when to think globally.

Students MUST learn how to think about change. Change is changing. It is changing at an increasing rate. Much of the information students learn today will be obsolete tomorrow. Teach students multiple ways to think and you give them a lifeboat.

Critical thinking is yet another important way of thinking. Chinese, Korean, Indian and other foreign ways of thinking are ever more important to students everywhere, especially in a global economy. Yin & Yang teach us how opposites can be complimentary.

Successful leaders think both inside and outside the box. To do that, they must know where the box is, its direction, if moving, where it started, where it's going, where are you relative to the box, what you want to change... There is almost always more than one right-way of thinking for any given situation. To be successful, one needs to learn how to think in multiple ways and when to apply each way of thinking.

I encourage you to explore how and why all students should learn how to think in multiple ways (a TD skill).

## 4.5 Think on Demand

Many professionals and other successful people can *Think on Demand*. They have learned how to focus their attention, explore issues from multiple perspectives and keep their mind open to alternative solutions, all at the same time. Thinking on Demand is like putting on a magic thinking cap. It is very important for students to learn to think on demand.

Think Tanks often use scenario planning to define and solve complex problems. Scenario Planning is an excellent approach for use in classrooms. Students should learn how to write scenarios and how to evaluate them.

When teaching students, to think creatively, be sure to “THINK CREATIVELY”. Following are 3 simple exercise that work surprisingly well:

1. Pose a simple problem and ask your students to think of 20 ways to solve it. Everyone participates.
2. Select a common physical or imaginary product such as a brick, a toothbrush, a toothpick, a lightbulb, etc. Ask your class to think of 100 ways to use it.
3. Start to tell a story. In the middle of a sentence, pass the story on to a student. The student adds to the story and passes it on to another student, who does the same until the allotted time has been used. The last student adds a conclusion.

## 4.6 Thinking Exercises

You can find many thinking exercises on the Internet. For examples, go to Google and search for the following key words: thinking, transdisciplinary thinking, business thinking, thinking exercises, thinking exercises for the workplace, business critical thinking exercises, brain trainer, mental practice, scenario planning, Transdisciplinary skills and Role Playing.

Thinking exercises improve thinking performance. Think of your brain as a muscle... the more you exercise it, the stronger it gets. Mental exercise helps the brain to detect and identify patterns and relationships. It also improves memory and concentration. Classes in ways of thinking will also increase student’s creative power and open their perspective on what’s possible.

## 4.7 Science Fiction Thinking

Wernher von Braun, the great rocket scientist, planned the whole earth to moon mission by working backwards. He told the story as though it was a press release that had already happened.

Arthur Clark depicted a conscious, intelligent computer that responds to spoken instructions and communicates audibly with astronauts on a space craft in 2001 A space Odyssey. Try it on your computer... today.

Jules Vern talked about water being burned from its base elements (H<sub>2</sub>O) in the future. That’s what Hydrogen Fuel Cells do.

## 4.8 Management Thinking

There is a simple management rule that permeates virtually all business activities. That is,

“If you cannot measure it, you cannot manage it and if you cannot manage it you can be in deep trouble, without knowing it”.

For the most part, after graduation, engineering students go to work for companies who treat engineering departments as cost centers... that's short-term thinking. What would happen if, instead of being expensed, engineering and R&D were treated as Assets that are amortized over their useful life, just like any other asset... that is long-term thinking.

By treating engineering and R&D as investments, they would automatically appear as assets on the Company's Balance Sheets, instead of disappearing, which is what happens when they are expensed. Engineering and R&D would instantly become Intellectual Property (IP). Management would better understand the role and importance of engineering and R&D in your organization.

I am not going to spend more time talking about Management Accounting, except to say that how management thinks about engineering and R&D is important. You might be surprised to learn that your business organization uses GAAP and Tax Accounting and non-profit organizations use Fund Accounting, but very few organizations think in terms of Management Accounting.

## 4.9 Napoleon Bonaparte

Sometimes military conclusions are spectacularly wrong, often because of short-term thinking. They had not yet learned that we do not live in a surprise free world. Here is a world changer.

In 1805, Napoleon Bonaparte (Emperor of France) dismissed American engineer, Robert Fulton, (inventor of the steamboat) for suggesting that Napoleon could use steam powered ships to defeat the British Navy. Napoleon's response was, "What, sail upstream against the wind with a bonfire under me deck? I pray you excuse me. I have no time to listen to such nonsense."

Just imagine how different the world would be today if Napoleon had a long-term perspective on ship propulsion, accepted Fulton's proposal and defeated the British Navy.

## 4.10 Railroad Transportation

In 1869, the presidents of the Union Pacific and Central Pacific railroads met in Promontory, Utah, to drive the ceremonial spike that connected their railroads. That made transcontinental railroad travel possible, for the first time.

Railroad tycoons defined their business as the railroad business. If they thought of their business as the mass transportation business, they would probably own the airlines. And if they defined themselves, as being in the transportation business, they could have owned the airlines... and the truck/auto business too.

## 4.11 Status Quo Thinking

This next example illustrates the conflict between short-term and long-term thinking.

You may be surprised to learn that the motion picture industry has been short-sighted, since its inception. It has opposed every technological advance throughout its history. On the other hand, the long-term thinkers on the technology side have persisted and are the significant winners. For many years, motion pictures were limited to silent very short stories (1-reelers)... no sound, no color. Movie moguls who controlled the industry wanted to maintain the Status Quo because it was profitable, comfortable and controlled.. by them. Screen words were used to help the audience follow the story. There were no spoken words because, “no spoken words were needed” and “the voices of the actors was not appealing”. More short-term thinking.

Finally, 2-reelers, with better, longer stories were accepted. In 1927, the “Jazz Singer” starring Al Jolson broke the sound barrier and introduced “the talkies”, feature-length motion pictures.

For years, the Motion Picture Studios refused to sell motion picture features to television networks. When watching television became an American habit, it became clear that the television set makers wanted to continuously introduce new, bigger screens and higher resolution TV sets. The movie makers were dragged along, against their will.

The studios also refused to sell features to Home Video until Shelly Saltman, President of 20th Century Sports, sold 50 FOX features to Magnetic Video. That started the Home Video industry. Every other Motion Picture Studio tried to convince FOX not to honor the sale. FOX held fast. In 1978 the California District Court ruled in favor of Sony on a case Universal and Disney filed in 1976. That case ended the question of copyright infringements.

Even though every effort by the motion picture industry to stop the growth of technology failed, the industry prospered. The motion picture industry benefited because of the long-term vision of the technologists. The motion picture industry, commercial and pay television, the manufactures of entertainment and information equipment and most importantly, the public would be much better off today if long-term thinking had been applied by the studios then and now.

## 4.12 Thoughts on a University without Classrooms or Lectures

According to Wikipedia, education is defined as, “the process of facilitating learning, or the acquisition of knowledge, skills, values, beliefs, and habits.” Wikipedia goes on to say, “Formal education occurs in a structured environment whose explicit purpose is teaching students. Usually, formal education takes place in a school environment with classrooms of multiple students learn-

ing together with a trained, certified teacher of the subject.” So we start with facilitating learning and arbitrarily link that to doing it in a structured school environment with classrooms and lecturers. It doesn’t have to be that way.

The essential characteristics of education requires the presence of following 3 elements:

1. the participation of learners (students),
2. the availability of information to be transferred to the learners and
3. a means of transferring the information to the learners.

**The Challenge:** Not long ago, tomorrow was very much like yesterday. That time is past. Man’s knowledge is doubling at a dizzying rate. Some say the doubling occurs every one to two years. Others estimate the doubling to take place every 11 months. In either case, the current education architecture is woefully inadequate.

**Technology And Evolution Are The Answer:** When evolution created sight, it was a game changer. When man developed computers, memories and processors it too was an evolutionary game changer. *Mankind is evolving through technology.* It appears the growth of man and machines is limited only by man’s imagination. Obviously, that means we need to increase man’s imagination power. We can do that through education, but not the kind of organization that requires students to sit in classrooms and listen to lecturers. As Einstein said, “Imagination is more important than knowledge” and “Education is NOT the learning of facts but the training of the mind to THINK”.

#### **4.12.1 How Will Education Without Classrooms Or Lectures Work?**

There are many alternatives to the current education structure of classrooms and lectures. Here are 2 such alternatives.

##### **Solution Based Learning (SBL)**

Under an SBL structure, a team of students, led by a coach, is assigned to solve a complex problem (the “Opportunity”). The students have access to the sources of information needed to generate a unique, practical working solution, for the Opportunity. The student team(s) organize, divide, sequence, characterize and solve the Opportunity. Innovation and invention are encouraged.

A competitive characteristic can be added to SBL by using Duplicate Bridge rules. Essentially, multiple teams start with identical information. They proceed along independent lines of inquiry.

### **Immersion Based Reality (IBR)**

The processing and display requirements for Immersion Based Reality, including Virtual Reality (VR), Augmented VR and Holographic Reality (HR) are available today. IBR learning can be thought as an extension of a theme park dark ride such as, “Back to the Future” or “Spiderman”.

Learners will enter an IBR stage, don a face mask and sit in a motion controlled vehicle (for one or more people). The integrated IBR visual display and physical motion will immerse students in the learning experience.

Many different learning experiences can be made available on a single IBR system. For example, one learning experience could be a trip through the blood stream to the heart. Another trip could be space travel to a distant planet. Yet another experience can be training for the repair of auto transmissions, etc.

Each of these experiences could be designed to serve students at multiple levels of sophistication. The vascular trip could display versions suitable for young learners, for pre-med students and for vascular surgeons.

Quantum computers are currently solving some complex problems faster than digital computers can do the job. Quantum computers are still rare and costly. That condition won't be true for long. Prepare for another knowledge accelerator.

## **4.13 Conclusion**

From the Commissioner of the US Patent Office to Jules Verne, Napoleon, Hollywood and the entertainment business and even a different way to think about accounting, we have seen the power of thinking. You can multiply that power by teaching your students the many ways thinking. Thinking is mankind's most powerful tool. Learning how to use it to make a better world is mankind's greatest challenge. Incredibly, man's knowledge is doubling every 2 years. Our machines are improving to support that growth. We must improve ourselves to keep growing.

Education provides the means of improving mankind's ability to think and to imagine. It is an essential step in the creation of man's future.

Man has created a world unimagined only a few generations ago. There is much more to do

Rene Descartes said it all.

I THINK, THEREFORE I AM

Think About Thinking.

## About the Author



**Bob block**, is a Founder and a Managing Partner of LiTricity, a shareholder and Board member of USCL and the Co-Chair of the Advanced Technology Policy Committee of the National Energy Marketers Association. Mr. Block has extensive experience in the computer software, communication, energy and entertainment industries including pioneering roles in commercial and pay television and cellular telephone operating companies. He has also contributed significantly to the creation and development of entertainment and communication technologies used worldwide. Block is widely known for his pioneering work in communications, information and management technologies. He is the inventor and patent owner of more than 150 issued US and International patents, including patents relating to: Enterprise Management Systems, Information Labeling, Signal Control, Terrestrial and Satellite Distribution Systems, Real-Time Subscriber Billing Systems, Pay-Per-View, Parental Control and English Language Education. Block has multiple patent applications pending, including patents relating to interoperability of non-compatible radios, power metering and solar energy systems. Block's inventions are licensed to most of the major consumer electronics manufacturers and have influenced entertainment, sports, and information and education services worldwide.

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# CHAPTER **5**

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## The Science of Bee Collapse and an Emerging Knowledge for Sustainability

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*The following text addresses the threats affecting the honey-bee, and which are manifesting through the unusual death rates of bee colonies. Focus is placed in reviewing the scientific knowledge that concerns the honey-bee by discussing its cognitive and ethical categories and its influence in nature conservation, mainly centred in the EU. Results indicate that scientific knowledge plays a fundamental role in defining what the problems are, as well as their degree of urgency and holds the greatest legitimacy in informing policy-making. Further results reveal that research is dominated by STEM fields of science, and is largely conveying a dichotomized and utilitarian viewpoint of human-nature relationships. The concluding section argues for a transition towards transdisciplinarity and social learning. It emphasises a science that is able to integrate a social-ecological understanding of the value of bees as the world's common good, together with a praxis that effectively promotes sustainable change.*

**Keywords:** Honey-bee collapse; nature conservation; science; transdisciplinarity.

### 5.1 Introduction

The following text is based on research underway about the life and death of the honey-bee understood within the dynamic wholeness of Earth's human-environmental relationship. In this research I set out to understand the significance of the threats affecting the honey-bee, and which are becoming apparent through the unusual and sometimes drastic death rates of bee colonies (Potts

et al., 2010; William, 2010) [1] [2].

Science points to the demise of the honey bee as one instance of a larger picture, in which fellow insect pollinators are reported to be in decline in many regions of the world (Potts et al., 2010; Vanbergen, 2013) [1] [3]. It has been estimated that 87.5% of flowering plants are pollinated by animals. This covers both crop and wild plants, and points to the crucial importance of bees – as one of the chief global pollinators – to the maintenance of food production and wild plant ecosystems (Ollerton, 2011) [4]. Not surprisingly, the past decade has seen a considerable amount of research conducted on the collapse of bee colonies. Despite a variety of inquiries, unanswered questions and blank spaces, scientists agree that the syndrome has a *multifactorial nature and anthropogenic* origin.

My research also points to a maze of multi-dimensional aspects that compose a remarkably complex tapestry. Its strands involve not only the ecological intricacies of the biosphere, of which bees are fundamental attendants, but also the impact of a plethora of human ideas and practices. These encompass conservation policies and regulations, apiculture, agro-chemical corporate manoeuvres and scientific models of understanding the natural world. This chapter mainly addresses the latter, through a critical review of scientific knowledge concerning and affecting bees.

In nature conservation, scientific knowledge plays a fundamental role in defining what the problems are, as well as their scale and their degree of urgency. The case of the honey-bee is no exception. Science holds the greatest legitimacy in informing policy making, ranging from regulatory frameworks to the implementation of protective measures. For example, the European Commission's recent attempt to remove certain pesticides from the market was based on large amounts of scientific research demonstrating their negative impact on the honey-bee (CFP, 2009; EFSA, 2013; UNEP, 2010) [5] [6] [7]. Scientific research also has a large influence on modern apiculture: 'good' beekeeping practices and technologies get promoted through different venues, and beekeepers are increasingly dependent on pharmaceutical products to ensure the livelihood of their colonies.

The collapse of bees seems to have become a vortex around which a series of key pressure factors revolve. One of the main factors is land-use, which includes growing urbanization. This fragments and destroys many natural habitats that bees, like other pollinators, rely on for their livelihood (Garibaldi et al., 2011) [8]. Agricultural intensification often leads to the use of pesticides that harm bees. In addition to the use of pesticides, various modern beekeeping practices cause stress and malnutrition. For example, continually relocating beehives and the increasing use of sugar, instead of honey, to feed colonies. Other stressors include the practice of selective breeding with its related problematic consequences (Tarpy, 2003; Meixner et al., 2010) [9] [10]. There is also the rampant pressure produced by pathogens, such as the notorious parasitic mite *Varroa destructor*. As a consequence of the ubiquitous presence of pathogens, beekeepers often resort to chemotherapy (Johnson et

al., 2009) [11]. Managed honey-bees are thus chronically exposed to a cocktail of different chemicals that can interact, sometimes synergistically, with detrimental effects on their behaviour, immunology and ultimate survival (Vanberg, 2013) [3].

Arguably, the death of bees is a fundamentally radical case for Nature Conservation. Firstly, on account of its impacts on the biophysical level. Because the life of bees provides the foundation for a most intricate web of relations in the planet, the risk of their demise points to a most colossal collapse. Secondly, because solutions involve seeing the complexity of a much larger set of human-environmental relations, and involve changes in deeply entrenched institutions and their functions.

The most radical problems naturally call for far-reaching answers, which I argue require moving beyond the death of bees as a collective bio-physical threat to an understanding of the life of bees as a common good. This change presupposes a considerable paradigmatic leap in the way science and knowledge is used in the pursuit of sustainability. The challenge of this paradigm shift lies at the core of effective Nature Conservation and its failure to respond to the situation at hand. In the next section I address some of the key challenges of this transition. In the last section I argue for a new model and praxis that recognizes that the complexity and urgency posed by the fate of bees demands an integration of science and social transformation.

## 5.2 Challenges of Transition

### 5.2.1 Taking on Board the Human Dimension

The key pressure factors identified in relation to the collapse of bees, such as land-use intensification or particular models of agriculture, point to multiple human-environmental aspects, thus naturally calling for interdisciplinary approaches. Nevertheless, an overview of research reveals that the understanding of the collapse, like other problems in environment and nature conservation, is largely dominated by the natural sciences and STEM fields of research<sup>1</sup>. However, the question remains whether it is possible to understand the collapse outside of its actual social fabric and bypass sourcing its anthropogenic roots.

In effect, the death of bees is immensely and unavoidably political. One has only to place research developed on bee collapse in its social context, and consider the thought-provoking fact that pesticides, the most researched and ‘objectively’ established factor of risk is also one of the most energetically refuted. The solidity of such findings informed the recent restriction adopted by the Commission, but this political decision was soon to be counteracted

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<sup>1</sup>It is revealing that the two latest scientific events on Bees in Europe have no formal participation from the social sciences, vide <http://coloss.org/home/conference/> and [http://eventos.um.es/event\\_detail/592/sections/166/symposia.html](http://eventos.um.es/event_detail/592/sections/166/symposia.html) (Accessed 11 August 2014)

by two large companies with agribusiness interests, Syngenta and Bayer, who have sued the EU<sup>2</sup>.

These legal actions, in turn, have to resort to scientific data that sheds doubt on previous research. Doubt, instrumental to science's method, can also become a powerful weapon. Anyone who has followed the Climate Change saga may well find in this new collapse saga remarkable similarities.

Furthermore, the production of knowledge on the life and death of bees is no longer confined to public bodies. Nowadays, large corporations like Monsanto are buying entire research institutions, promoting networking events, and forming new influential bodies, such as the Honey Bee Advisory Council, an alliance comprised of Monsanto executives, researchers and beekeepers<sup>3</sup>. These developments eloquently reveal how the death of bees can only be fully understood and addressed in the meeting of science, politics, and corporate economic power.

A transition towards a science for sustainability supposes not so much taking on board the human dimension – because it was never absent in the first place – but promoting thorough awareness and reflexivity amongst researchers in regard to mutual influences and potential impacts of such triangulation.

### 5.2.2 Science in culture

Research announces the ecological value of bees as veritable pillars of biodiversity. However, very often this ecological, instrumental value, is translated into a social value with apparent naïveté as to its canons and potential consequences. Reports, particularly those with outreach ambitions into civil society, frequently convey information in this fashion:

“The Food and Agriculture Organization of the United Nations (FAO) estimates that of the 100 crop species that provide 90% of food worldwide, 71 are pollinated by bees. The majority of crops grown in the European Union depend on insect pollination. Beyond the essential value of pollination to maintaining biodiversity, the global annual monetary value of pollination has been estimated at hundreds of billions of euros. In view of the important ecological and economic value of bees, there is a need to monitor and maintain healthy bee stocks”<sup>4</sup>.

The life of bees and its value is consequently being associated with food production, and its corresponding monetary value. Indeed, this translation ac-

<sup>2</sup><http://www.europeanvoice.com/article/2013/august/syngenta-challenges-eu-pesticide-ban/78075.aspx> (Accessed 11 August 2014)

<sup>3</sup>Monsanto acquisition: <http://naturalsociety.com/monsanto-bee-collapse-buys-bee-research-firm/#ixzz1swcD6H4T>; [http://www.huffingtonpost.com/richard-schiffman/the-fox-monsanto-buys-the\\_b\\_1470878.html?view=print&comm\\_ref=false](http://www.huffingtonpost.com/richard-schiffman/the-fox-monsanto-buys-the_b_1470878.html?view=print&comm_ref=false). Monsanto's advisory council: <http://news.monsanto.com/press-release/sustainability/monsanto-company-forms-honey-bee-advisory-council-pledges-support-honey> (Accessed 11 August 2014)

<sup>4</sup>In EFSA website: <http://www.efsa.europa.eu/en/topics/topic/beehealth.htm> (Accessed 11 August 2014).

curately expresses a powerful trend in the management of Nature Conservation known as Ecosystem Services.

Given the social legitimacy of science in describing the world ‘as it is’, the idea of anchoring the life of bees in its instrumental value – widespread in the media and used as the main rationale by policy makers – runs the risk of becoming ‘natural’ and of hiding the fact that it carries an ideological assertion.

When instrumentality is the main operative standpoint of value, solutions and problems become strangely similar. At present, laboratories in Europe are dedicated to reducing potential sources of honey contamination caused by both foraging contaminated nectar and chemotherapy of honey-bee diseases. One of the strategies to address these problems involves genetic manipulation, that is, selecting and breeding “disease resistant stock”. This is made possible “because the complete honey-bee genome (*Apis mellifera*) has become available, establishing this economically and ecologically essential organism as a model system for genomic research” (my italics)<sup>5</sup>.

This solution poses two problems. One expresses the typical environmental ‘technofix’ whereby a counter-technology is developed to oppose and neutralize the negative effects created by other technologies. In such an approach the habitual pattern is to overlook the unintended consequences, in this case, of genetic manipulations which are eloquently captured in the second law of thermodynamics: “Each technology always creates a temporary island of order at the expense of greater disorder in the surroundings” (Huesemann and Huesemann, 2011, p. 19)[13]. Such fixes commonly bypass the dire need for “a conscious effort to direct technological innovation toward the achievement of clearly defined societal goals that reflect shared values” (Ibidem:116)[13].

The second problem with the solution relates to its unexamined ideological nature. Framing the existence of bees as producers of ecological services is tacitly in line with the representation of the biophysical world as reservoirs and stocks of ‘capital’ and therefore to be part of the market.

Once particular conditions of production are colonized in this way, it becomes possible to justify their management by economic rationale. That is, environmental degradation and resource exhaustion are being seen as management problems rather than a civilization crisis. Such narratives steers us away from the difficult politics of solving structural inequalities and differentiated interests, in favour of “technomanagerialist remedies, preferred (and constituted) by elite, scientists and bureaucrats” (Goldman and Schurman, 2000, p. 567) [14]. In sum, the prospects of such solutions are set within the commodification of nature in which species become alienable market goods, a solution that seems to be in collusion with the very problem to start with (Kosoya and Corbera, 2010) [15].

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<sup>5</sup>[http://www2.biologie.uni-halle.de/zool/mol\\_ecol/bee-shop/behav\\_genet.html](http://www2.biologie.uni-halle.de/zool/mol_ecol/bee-shop/behav_genet.html) (Accessed 11 August 2014). The opening of the genetic research field covers other aspects beyond those of food production. For example, the case of the honey-bee being re-designed to serve military purposes (see Kosek, 2010) [12].

A transition is underway insofar as there are signs of awareness of the serious consequences of what could be called an epistemological short-sightedness. This awareness comes from different sources (Suryanarayanan and Kleinman, 2012; Matthews, 2010) [16] [17] including the most reflexive quarters of those advocating ‘economic values of ecosystem services’ (Kumar, 2012) [18]. A cultural analysis of science stresses the fact that all human understandings of nature are crucially mediated by social and cultural practices, assumptions, and belief systems. Moreover, such understandings have different impacts and consequences in our relationship with other beings, such as bees. Therefore, there is a need to question science on account of its virtually invisible cultural constructions. “The point of such an interrogation is not to debunk scientific knowledge, but rather to expose its unspoken social and moral commitments” (Wynne, 1994, p. 188)[19]. Yet, hardly any such self-reflexivity transpires in mainstream research dedicated to the collapse of the honey-bee. Moreover, the exceptions to this trend seem to play a negligible role in informing nature conservation management.

### **5.2.3 Responding to Uncertainty and the Unknown**

*Uncertainty* is commonly identified as one of the central aspects of human-environmental systems and indeed comes as one of the main aspects that research on bee collapse refers to. As we meet some of its empirical instances, it becomes apparent that the way we respond to uncertainty and the unknown expresses different modalities of knowing which in turn suggest different ways of relating to nature. Concerning the collapse of colonies, uncertainty starts with the very definition and criteria of what constitutes the problem, as “there are many inconsistencies in the ways in which ‘colony losses’ are defined” (Hendriks, 2009)[20]. From here on, uncertainty spreads to any “exact reasons” that link to recent increases in bee mortality (Tabajdi, 2011) [21].

The importance of defining the problem is worth considering. Here Einstein’s famous quote gives us the clue when he reportedly stated that if he had an hour to solve a problem, and his life depended on the solution, he would spend the first 55 minutes determining the proper question to ask.

In social sciences, the importance of such procedure has been identified as framing, here understood as the interpretation process through which individuals, groups, and societies organize, perceive, and communicate about reality.

It is clear, therefore, that in a science for sustainability, where research aims to answer not only biophysical but social and political relevant matters, there is the need to share and agree on how problems are framed. This is crucial, as it influences the way in which research will be carried out and communicated, as well as its potential outputs to be used in decision-making processes. Even though it is unusual for research questions to be framed jointly with other stakeholders, some transition steps are being taken in that direction in nature conservation (Young et. al., 2014, p. 392)[22]. Given its novelty and

uncertainty, the case of colony collapse seems most apt to be framed and reframed in and outside academia. For researchers this implies sharing not only their expertise but also their uncertainties in a wider pool of knowledge that includes a range of social actors, such as bee-keepers, farmers, activists and policy makers.

In understanding the demise of bees, uncertainty is also related to empirical intricacies, particularly the need to carry out an extensive and thorough monitoring of what is happening to the honey-bee as well as the need to further articulate this information. Yet – and taking the European case as an example – researchers report that there is a general weakness and high variability in most of the surveillance systems (Hendrikx et. al., 2009; Potts et al., 2010) [20] [1] and therefore a lack of “reliable and comparable data on the number of hives, beekeepers and colony losses in the EU” (Tabajdi et al., 2011) [21].

The challenges of uncertainty are being addressed by researchers, policy and funding bodies in different ways. One approach favours the daunting task of fostering converging platforms across Europe. This approach involves managing the immense plurality and fragmentation that is inherent in diverse socio-economic and political contexts in which the monitoring takes place. One example is the implementation of the pan-European epidemiological study on honeybee colony losses (EPILOBEE, 2012–13). Because the focus of such survey is centred in ecotoxicological aspects, there is nevertheless ample room for knowledge to be produced also on social, political and ethical variables. In addition, methodologies for building knowledge that include participation and communication should be encouraged, albeit being resource intensive and hard to impress upon funding bodies (Wals et al., 2009)[23].

Other approaches seem to prefer bypassing the development of social-oriented approaches in favour of using technology as a panacea. Perhaps that is why in a FAO report concerning pollination services, the development of a new radical solution is expressed in enthusiastic terms: “DNA barcoding works for bees (...) the long term objective of the barcoding enterprise is to have almost all organisms on the planet identifiable with a hand-held device that can generate a DNA sequence and communicate with a global database through wireless technology” (FAO n/d, p. 5) [24].

This radical codification measure against the uncertain and the unknown brings the promise of shedding light on the obscurity of bee collapse by creating an understanding that thoroughly computes the life of bees. But will such sweeping profiling bring greater acumen in humans’ relationship to bees and ultimately nature conservation?

As we have seen, techno-fixes need careful reflection, not least because they spring from a tradition that has concocted objectification and control as key ingredients in addressing nature’s mysteries. Many argue, and convincingly so, that these ingredients mark the onset of modern science. Some of its illustrious fathers, such as Francis Bacon and René Descartes, made clear secular confessions concerning the intercourse between knowledge of nature and the will to power (Coimbra, 2006; Merchant, 2006)[25] [26].

Nonetheless, from the onset of modern science other voices sustained alternative viewpoints. Notably, within the Romantic Movement, nature was a privileged field of knowledge precisely because it stood as the realm of reality less explicated by humans and as such it constituted the best choice for the Romantic experiment. Claiming that important facts of nature are lost when we reduce them to quantities and tangible surfaces, the Romantics were not so much nature poets as reality-experimenters, seeking to reconstitute the wholeness of knowledge by adding their experience of value as a feature of reality<sup>6</sup> (Everden, 1993)[27]. Later, scientist and environmentalist Aldo Leopold also re-envisioned the enterprise of science through similar lines, by questioning the meaning of perception, of our experience of the 'other,' and of the dichotomy of 'subjectivity' and 'objectivity'. This re-envisioning was carried through within the field of ethology by Jakob von Uexküll. He introduced the concept of *Umwelt*, proposing to understand how the world exists for the animal, given its own particular characteristics. Such perspective sustained that animals too live in meaningful worlds, and that meaning is bestowed by the organism-subject on its environment (Uexküll, 1957)[29]. Contributions such as these have had a far-reaching influence on alternative worldviews in science and environmental philosophy and still hold great potential for future exploration (Bartof, 1996; Bateson, 1972; Næss, 1989) [30] [31] [32].

Science demands to be understood as part of our history and cultural development. The commodification strategies and unrevised techno-solutions as answers to the death of bees are just new avatars of a form of knowledge that is still anchored in seeing nature and its subjects as objects to be probed and controlled, thus obstructing real innovation and new forms of relation that are conducive to sustainability.

In summary, an analysis of research on bees reveals the possibility of having a change which fittingly agrees with what has been called the transition from Mode 1 to Mode 2 Science (Nowotny et al., 2003) [33]. In the case of colony collapse, research seems mostly centred in the first modality, which emphasizes objective and value-free science, preference for technical solutions, and interrogation of conventionally defined natural 'others'. A transition towards a second modality entails giving further steps into complexity's pool of knowledge, by including the interaction between actors, structures and phenomena and the related convolution of managing human-environmental systems throughout uncertainty and epistemological creativity.

Given the dominant role of science in shaping nature conservation, it follows that different modalities of knowledge have a large impact in decision-making and ultimately on the life and death of bees. The actual transition from a traditional mode of science to a new paradigm seems at least as central to the

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<sup>6</sup>It is worth noting that the Romantic Movement, like other major movements, has had both a shallow and a deep side. Unfortunately Romantics became known as utopian, sentimental and regressive. Our reference here, however, takes into account the intellectual and artistic stature of representatives such as Novalis and Schiller. The latter envisioned the relation of humans to nature through a culture which "does not bring back man to Arcadia, but leads him to Elysium" (Schiller, 2006)[28].

fate of bees as producing more research per se. But the buzz in concepts like ‘interdisciplinarity’ or ‘participation’ should not blind us to the fact that such transition knows many covert obstacles, not least the inertia of cognitive conformism, particularly when this rests on extremely powerful and deeply seated institutions, and so business runs on, despite stern messages that business as usual is not an option.

### 5.3 A way Forward

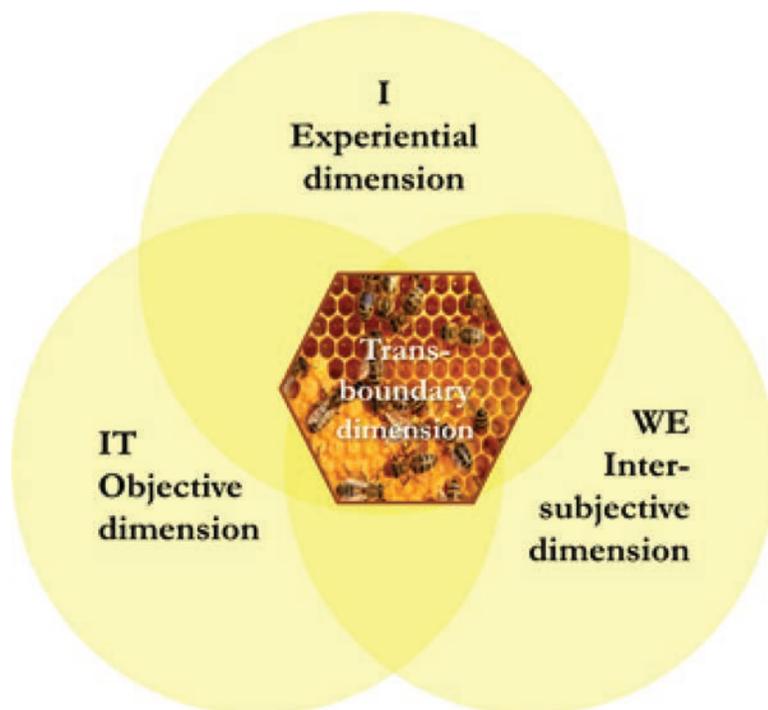
The death of bees is showing us that the mainstream model of Nature conservation is not endowed, conceptually and practically, to deal with the complexity and urgency it entails. The solutions it engenders – at their root – often seem to collude with the problems to begin with.

According to such a model, the demise of bees is often understood and communicated as an environmental risk with ominous economic consequences. The value of bees reaches civil society and the political sphere through ecological and economic rationality, wrapped in the fear of impending catastrophe. It seems indubitable to assume that the death of bees serves no interest on Earth and inversely, that the flourishing of their life is to everyone’s interest, and can therefore be understood as a common good. But what is common, and moreover good?

Scientific knowledge has been the main player in framing, if not a common good, a common ground, on the implicit account that the biophysical objective reality is human’s common ground. However, as innumerable research has demonstrated, nature cannot per se be a common ground because it is inextricably woven into culture and therefore is socially constructed, immensely plural and unequal. It follows that, in defining a common good, it is insufficient if not misleading to reduce it to an ecological and economic rationality. Such rationality cannot cover the full spectrum of value and meaningfulness embodied in the life of bees and, moreover, it hasn’t been able to ignite the transformations urgently needed in order to recognize it and uphold it.

I argue, therefore, that a science for sustainability has the capacity to unleash a much more powerful social *understanding* of bees as the common good of humanity together with a social praxis that effectively promotes sustainable change. But in order to carry this through, science needs to embody the change it preaches, which means first and foremost to question some of its deeply seated assumptions. Otherwise, it will continue to be more part of the malaise than of the cure.

One foundational assumption rests on the dichotomy separating human subjectivity and objective nature. This division is becoming increasingly problematic as anthropogenic causes are becoming evident and acute. Yet, as we have seen, the knowledge production most dominantly working through Nature conservation is still entrenched in the “great Western paradigm,” formulated by Descartes and imposed by developments in European history since the 17th century (Nicolescu, 2010)[34].



*Figure 5.1:* Trans-boundary model.

It is possible to overcome this dualism by purposely adopting a model that can reunite and integrate objective and subjective dimensions of knowledge and in which multiple factors – ecological, economic, political, and normative – find their indelible correspondence. We have already very valuable contributions in this direction, namely in the development of a science animated by ‘strong transdisciplinarity’, such as proposed by Nicolescu (2010)[34], Max-Neef (2005) [35], and Morin (2005) [36]. Methodological contributions have been developed also in agreement with such epistemology and with effective capacity to create sustainable change (Scharmer et al., 2009; Wals et al., 2009) [37] [23].

The combination of these approaches, when applied to bee research, can be translated into a model and a method to address nature conservation. The model outlined here seeks to provide stakeholders with a learning, transformative process that is grounded in three main dimensions of knowledge – objective, inter-subjective and experiential (see Figure 5.1). Their intersection form a trans-boundary dimension where a pragmatic, real-life sustainability concern can be defined, designed and implemented. Simultaneously, it is also the podium from which the understanding of a common good may emerge.

The “IT” dimension, also known as 3rd person knowledge, is the sphere of data and analysis of objective and inter-objective realities. Here participants



*Figure 5.2:* Courtesy of Phillip Cairns.

can identify relevant social and ecological variables correlating to bees, for example, in assessing the impact of GMOs or analysing EU conservation policies. So far, this has been the dominant, mostly exclusive sphere being developed in the case of bees (Figure 5.2).

The intersubjective sphere of “WE”, concerns relational knowledge. It comprises an understanding of cultural plurality and the learning of communication and collaboration skills in the context of nature conservation.

The challenge here is to understand that pesticides, monoculture or malnutrition are only the downstream symptom of bees’ main problems, which in fact are the lack of mutual understanding and mutual agreement in the human sphere about how to proceed with these problems. ‘Saving bees’ thus depends primarily on human beings being able to reach mutual understanding and unforced agreement as to common ends. And that intersubjective accord occurs only in the cultural-communicative sphere.

Mutual understanding and agreement, however, can only be reached based on a moral, non-egocentric perspective concerning the global commons. And we reach such perspective through a challenging and laborious process of inner development that, even though it can be fostered by constructive communication, is ultimately an individual process.

Thus we reach the third, and less recognized sphere of knowledge, the experiential dimension of the self. So far, in nature conservation, the individual human being is considered solely as part of a social system. Here, however, the individual – not reducible to the collective – figures as a defining feature of this new model.

The experiential sphere or 1st person knowledge is the core field of transformative learning and includes all manner of actors understood as knowledge producers and potential change makers: the beekeeper, the farmer, the scientist, the policy maker and the normal consumer, considering his/her daily choices of food and bee-related products.

A transformative learning process is capable of promoting autonomous thinking functions (revision of belief systems), feeling functions (revision of attitudes towards self and others) and willing functions (behavioural changes in lifestyle). In other words, it fosters self-awareness and social intelligence in the way we relate to others, human and non-human, like bees.

Beyond mainstream, a long standing tradition exists in science of anchoring self-reflexivity and experience, namely in the phenomenological tradition in which Johann Wolfgang von Goethe, a precursor, stated: "Insofar as he makes use of his healthy senses, man himself is the best and most exact scientific instrument possible" (Goethe, 2010) [38]. Grounded in the individual, the 'delicate empiricism' advocated by the Goethean science promotes a knowledge of relation, an intimacy that not only deepens intellectual understanding of animals and their life patterns but also strengthens empathy. This integration can have significant implications. Studies conducted on education based on such inclusive methods demonstrate that "students feel themselves to be more in harmony with the phenomenon, as if themselves were participating in it. This leads to an attitude towards nature more grounded in concern, respect and responsibility" (Bartof, 1996, p. 25) [30].

A science for sustainability is one that is able to engender such connection, in which the subject (observer) becomes the object (observed) and the object (bees) become a subject in their own right, collapsing the standard scientific divide between them. Such connection fosters an observation with a feeling for qualities that are to be found in the natural world, and by which it remains alive, dynamic, undivided and profoundly meaningful to the self. In short, a science of the wholeness of nature.

Such experiential knowledge, anchored in oneself, reunites fragmentation of thinking, feeling and willing. For we know more deeply by understanding what we know, through feeling what we have understood, and by putting into practice what we have understood and felt. Once found in the individual, the common good ceases to be an abstraction. Nevertheless, to be able to reach it we must, in the words of Gandhi, be the change we want to see in the world. And that, despite the buzz in the word change, seems to be remarkably challenging.

Yet, such integration must produce other ways of understanding bees beyond seeing them as "economically and ecologically essential organisms", and consequently lead to other solutions which are more coherent to finding the common good for humans and bees alike.

In nature conservation it is imperative that before deciding on strategies and management plans, social actors decide upstream what the common good is. From a methodological perspective, this implies building a common frame

of reference amongst different parties and working to reach agreements on a set of foundational values that are congruent with a desired direction of development in the thriving of the life of bees.

In practice, when bringing people together – like farmers, bee-keepers of different orientations, policy makers, and scientists – we come across the immense plurality of values, attitudes and belief systems that humans hold in relation to nature. As can be noted by any seasoned observer, this plurality often leads to fragmentation of multiple identity groups with few perceived shared interests. On a larger scale, “the association of multicultural policies and environmental conservation has set the stage for competing ownership to natural resources and knowledge systems” (Kumar, 2012, p. 159) [18]. In working with diverse groups, we typically tend towards extremes; either difference turns into conflict and there is a sliding back, or people reach agreements and solutions that are shallow or mediocre.

However, there has been considerable development in the creation and implementation of new social technologies geared into sustainable transformative processes. Such technologies are able to work with plurality and dissonance as a way of formulating innovative solutions (Wals et al., 2009) [23].

Epistemologically speaking, it is necessary to consider that convergence is not to be understood as dissolution. It is simply a steering away from the standard scientific principle of disconnection (between disciplines, subject and object) in favour of a principle that maintains the distinction of parts but that tries to establish their relation. As Nicolescu asserts, unity in diversity and diversity through unity is inherent to transdisciplinarity (2010) [34].

Further, reuniting multiple dimensions of knowledge in the understanding of the human-environment ecological system shows that our social and cultural constructions of nature may be relative but have different consequences – some ideas or attitudes are unsustainable and go against objective life principles. Therefore, the model here advocated seeks to go beyond worldviews that are seized between a reductionist rationalism or by what Bourdieu called ‘nihilistic relativism’, in which all is equivalent to all, a dissolution between knowledge and opinion.

## 5.4 Some Final Remarks

The collapse of bees is a typical ‘wicked problem’ in that the problem is not understood until after the formulation of a solution (Conklin, 2006) [39]. In our case, the collapse can only be understood once the common good as the underlying premise of the solution is to be established.

It is also apt to add the collapse to the family of “super wicked problems” because “those seeking to solve the problem are also causing it” (Levin et al., 2012) [40]. It is worth considering that while research concerned with sustainability struggles to establish the causes and hazards of bee collapse, an even more voluminous body of research is being produced that can be directly linked to threatening the life of bees and ecosystems at large. Products of this

research include powerful synthetic pesticides, genetic manipulation beyond precautionary principles and in general the knowledge base for an agriculture still running under the auspices of the ‘Green Revolution’. But what kind of knowledge is thus being created and supported? A knowledge that celebrates the life of bees and strengthens appreciation for their existence or a knowledge that fosters their demise? Two irreconcilable strands of knowledge? Or a basic fragmentation of one knowledge? Yet there is only one planet, one life.

In this chapter, I have argued that the model of Nature Conservation, largely reliant on Science, is struggling to step into new modalities that are capable of dealing conceptually and practically with its multi-dimensional and interrelated facets. In the case of bee collapse, knowledge is still mainly reducing the human-environmental relation to its objective, biophysical aspects, thereby ignoring the profoundly woven political, cultural and experiential dimensions involved in the production of knowledge.

In order to respond to the great challenges invoked by the death of bees, a new approach is necessary, one that is able to understand and work through the complexity inherent in the human-environmental systems.

In the search for a common good, observation is inseparable from self-observation, criticism inseparable from self-criticism, processes of reflection inseparable from processes of objectification. This search requires developing integration of the observer-conceiver in the observation-conception and placing the observation-conception in its own cultural context (Morin, 1999) [41]. The sustainable common good embodied in the life of bees is, therefore, a matter to be situated in the integrity of epistemological pluralism, where the heights and depths of what we value need to be found and shared by means of quality communicative processes. No other field of human knowledge is more prepared to exert such systematic, uncompromising, critical pursuit, than a transdisciplinary science in service of sustainability.

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## About the Author



**Elsa Coimbra's** research is dedicated to nature conservation. In the last years her work has been focused on the relation between humans and certain species, like wolves, and more recently the honeybee, mainly within the scope of Europe. She has experience in working within trans-disciplinary environments and enjoy developing new models for human-nature relationships alongside social technologies for transformative learning. She has been promoting these action-research approaches with students in international programmes related to development and sustainability.

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# CHAPTER **6**

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## Qualitative Marketing Research, Neurosciences, and Transdisciplinarity

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*Qualitative studies often refer to the notion of the unconscious and neurosciences reveal to us the existence of a neuronal unconscious. But unconscious is not only neuronal, and the qualitative method does not offer ways to measure the mental reactions in individuals. In qualitative, we decipher the unconscious conditioned by our social, historical, and cultural environment; we read how the consumer projects himself onto the objects of the world; we tap into creative imagination; we can pull everything apart and reconstruct it; and we take part in the strategic objectives of a brand. For example, to construct a Brand strategy, we have to think differently; to break the beliefs; to think in a contradictory way. Qualitative is about going beyond the concrete facts and the measurements, which allows to think out of the box; it is about control and emerging meaning. In a world increasingly saturated with objective information, qualitative has a symbolic function that helps overcome the deadlocks of rationality. Qualitative is a transdisciplinary discipline.*

**Keywords:** Neurosciences, transdisciplinarity, qualitative research.

### **6.1 Evolution in Qualitative Studies: Always More Targeted, More Challenging and More Technical Yet Fundamentally the Same?**

Two different phenomena have changed our studies: new technologies and the Big data.

**1. The new technologies :** Internet, social networks, iPhone, iPad... but also all the new applications created everyday... all those new technologies have deeply

modified the human relationships, the way you communicate in the society, by creating a hyper connected consumer. One billion videos viewed daily on Facebook.

- The qualitative has changed with those innovations by creating methods of interview that are more direct and more interactive – online, on the go, diaries, blogs, communities...
- It has also changed by developing the methods that are adapted to those new relationships : ethnology, creativity, semiotics, video research and symbolical imagery...
- New principles have been created, either in the meeting rooms, in situ or on line This is the example of the Panorama group that changes the focus group. The principle is to take different contradictory targets who will confront together in the same room, or on line. It will generate solutions to the study problems.

**2. The Big data :** A second phenomenon has changed our procedures: the creation of larger data bases. The amount of data created every two years is about as much as since the beginning of mankind.

Those data bases help the companies to manage the markets: they establish new segmentations and new typologies, always more and more successful. Beyond the classic criteria of age, occupation, income level, consumption... we have to respect criteria that are more and more precise and complex in order to build our experience plans – ways of life, family structures, social networks, purchasing behavior...

The new technologies help us meet those new requirements and help us in our analysis by getting more and more realistic and operational.

**3. And qualitative research in all that ?** New technologies and Big data have changed our procedures and our techniques, yet they did not change the fundamentals of qualitative research, i.e.

- Avoid the pitfalls of a purely rational and declarative discourse
- Using images to help consumers express unconscious thoughts and the feelings
- Creative imagination to transform their expectations into real solutions

The question is: Are neuro sciences going to change our qualitative methods by inducing new procedures or are will they go as far as to change the fundamentals?

## 6.2 Neurosciences and the Fantasy of the Unconscious

**1. 80% of the brain activity is unconscious:** An iceberg is a picture that is often used to say that 80% of the brain activity is unconscious. But does this mean, that the unconscious is merely neuronal ? And is it possible to access this unconscious only via neuroscientific technologies ?

When I was a young man, as a clinical psychologist, I went to London in order to question the statue of Sigmund Freud about this...and what did Freud tell me? He said that the human psyche is divided not in 2 but in 3 different regions unconscious, preconscious, conscious. He told me: everything that is unconscious might become

conscious : in a dream of course, but also in free association of ideas , the Freudian slips, the play on words, and also in artistic creation - advertising is the best example.

Freud was right, the unconsciousness always finds a way to show itself to us, even if we are not conscious of such activity.

Renowned neuro scientists , such as G/erald Edelman or Antonio Damasio , have underlined the importance of the Freudian discovery. “The ideas of Freud about the unconscious sources of behaviors were premonitory. He stressed the importance of the unconscious processes that shape our behavior” G. Edelman.

### To conclude this first chapter:

- There different expressions of the unconscious
- ... and we can access it via language – but not any type of language

### 2. And how does the qualitative help us access the unconscious of the consumer? Via language of course, and in particular figurative language, which we can explore with:

- hedonical scales,
- verbal and graphic techniques,
- techniques using free association, but also creative techniques using analogies and symbolic imagery ...That is what Gerald Zaltman\*, marketing teacher in the Harvard Business School underlines when he talks about “figurative language” and when we talk about “symbolic imagery”: “the metaphors help to retrieve the unconscious thoughts, and help them to become conscious where they can be analyzed”.

It is obvious that if 80% of the brain activity is unconscious, this does not mean that its contents is locked forever into the unconsciousness.

Where neuro sciences give an interpretation of brain activity, Qualitative gives an interpretation of consumers’ words and behaviors.

## 6.3 Beyond the Unconscious: Creative Imagination

**1. Consumer imagination as a creative and prospective tool at the service of marketing.** Let’s talk now about the big difference between these two disciplines, which will – according to us – lead to different evolutions in the future.

We introduced creative techniques, like for example synectic, in 1969 in France.

The techniques of creativity use the power of imagination to overcome purely rational thinking, the level of opinions, in order to access a more spontaneous form of expression. Those forms of expression are much less influenced by social and cultural stereotypes, thus allowing for generating truly innovative ideas.

**2. The example of Tonigencyl** For example, in 1971, we conducted the first creative motivation study for Colgate Palmolive. The idea was very simple: we transferred the projective techniques used in clinical psychology to qualitative research, turning them into tools at the service of creativity.

Let's take the example of a new toothpaste concept research. One respondent within the group will be assigned to play the role of the mouth receiving the toothbrush. The imaginary toothbrush enters the mouth, rubs the teeth, the toothpaste begins to foam. Then, all of a sudden, the toothbrush starts to massage and caress the gums, who will shiver with pleasure! This is the beginning of Tonigencyl in France : the first toothpaste especially developed for sensitive gum.

**3. The creative forces of Qualitative** We surely know by experience, that we are all able to create beyond our social cultural and media references. Qualitative research is a place for imagination, creation, improvisation. The objective of our studies and tests is the creative transformation of a given stimulus, imagining it from always different angles, shaping it to meet our ultimate needs and to trigger our desires.

## 6.4 Client's Demand Towards Qualitative Research Have Changed

In the light of the progress made in science and technology, the function of Qualitative has changed.

A qualitative advertising test today is no longer limited to understanding the likes and dislikes, the elements of appeal and rejection and the purchase intent. Today our tests must answer more strategic questions, to help marketing and consumer insight teams within the companies to do their job.

**Let me give you a last example of new qual as it is done today: the new Nestlé Extrême commercial –** In order to pre test this movie, we started out with many hypotheses based on a lot of different stimulus material: a storymatic, several scripts, several boards, several pictures of the model and the historical commercials of the brand. This TV Copy is on air now, and it's very successful.

As you see, times have changed, from Tonigencyl to the new Extreme campaign, but not the fundamentals and the way we explore things in qualitative.

This type of questions clearly show the limits of a purely neuronal approach:

- The large number of variables to be tested
- The somewhat heavy procedure this would entail
- The nature of the questions asked
- And of course, the costs

For the time being, eye tracking, neuro imagery or any biometric methods will be somewhat difficult to use for evaluating complex marketing mixes and answering strategic questions.

## 6.5 Conclusions and Perspectives : Where does That Lead Us ?

**1. First conclusion: let's try to see how neuroscience and qualitative can complement each other** (see Table 6.1).

**Table 6.1:** Neurosciences and Qualitative Comparison

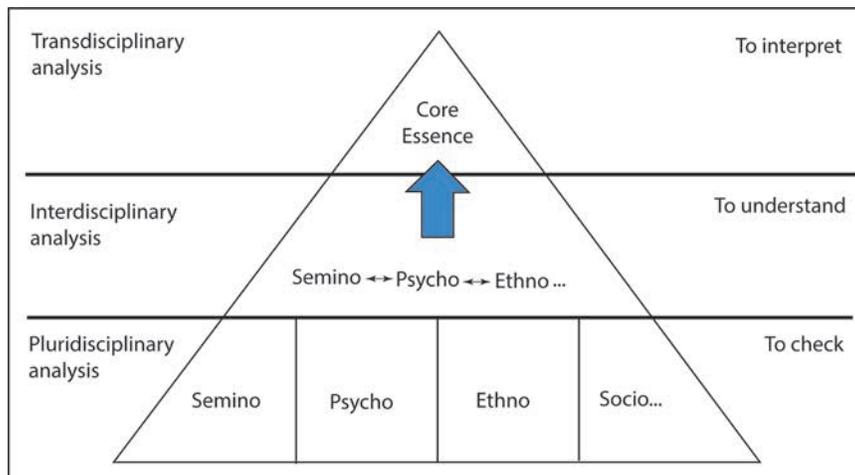
Neurosciences will explore	Qualitative will explore
<p>(the unconscious conditioned by our brain...)</p> <p>In neuroscience, we gain access to the unconscious conditioned by our brain</p>	<p>Whereas in qualitative, we can explore the unconscious conditioned by our social, historical and cultural environment</p>
<p>(Effects of the object...)</p> <p>In neuroscience, the answers we get are behavioral, by measuring the impact of a piece of stimulus on the consumer</p>	<p>In qual, we explore how the consumer projects himself (his desires, his past, his culture, his social background...) onto the object.</p>
<p>(brain activity)</p> <p>In neuroscience, we can measure the brain activity</p>	<p>In qual, we tap into creative imagination</p>
<p>(Perceive and build reality)</p> <p>In neuroscience, the object can be adapted and improved</p>	<p>(Deconstruct and reconstruct reality)</p> <p>In qual, we can pull everything apart and reconstruct it.</p>
<p>(Increasing measuring performance)</p> <p>Neuroscience has reached an amazing level of precision in the measurements, more reliable and faster.</p>	<p>(Increasing strategic relevance of recommendations)</p> <p>In qual, we take part in the strategic objectives of the brand.</p>

**2. Neurosciences will enhance performance and relevance of quantitative: more precise and faster measures and diagnostics** – For us, from all what we have just said, it is clear that neuro technologies will change the world of quantitative studies, more than the qualitative studies.

The big institutes, including the greatest communication agencies try to develop, as fast as possible, products coming from the neuroscience.

**3. A major risk for qualitative: become a servant of neurosciences** –

One of the greatest advantage of neuro technologies used with small samples is their rapidity and the reliability of their results. Be it online or face to face, we now can combine the neuronal and qualitative experience. Then, the mutual contributions of those two disciplines are obvious and they will get richer and richer, through the progress of technology.



**Figure 6.1:** Trans-boundary model.

But qualitative must not remain a pure servant of neurosciences : The appeal for science shouldn't imply that brands try to tame a consumer who is becoming more and more free and cheeky, informed and involved, and more and more willing to create a dialogue with his brands' stakeholders.

## 6.6 Qualitative Research and Transdisciplinarity

Eventually, this thinking about qualitative and neurosciences show that the qualitative research is a transdisciplinary method ; a method deployed through and beyond any discipline. Let's take the brand fundamental study, in order to understand the "Brand Essence", also known as "Core Essence", "Proprietary insight", or "Ultimate concept". A "brand essence" is a sentence that encapsulates in a few words every analysis data that will be translated into actions to be led, on different levels: the relationship system to establish between the consumer and the brand ; the word codes to use , the principles of communication to carry, the actions to lead in order to promote the products and to innovate. This work will help defining the strategical lines, the priority targets and their need states ; it will also help writing the brand architecture, and briefing Agencies and R&D.

In order to reach that Ultimate idea from which we will translate the different actions, we will have 3 degrees in qualitative research (see Figure 6.1):

- The first degree is multi disciplinary : it's about setting up the disciplines that need to be used (semiotics, semantics, linguistics, ethnology...) and this depending on the reality levels that will be studied (communications, packagings, products, behaviors...).
- The second degree is inter disciplinary : it's about crossing and overtaking the strengths and weaknesses of the brand, the stakes and challenges it will have to face in the competition environment.

- The third degree is transdisciplinarity: it is about control and emerging meaning, all about the wording for brand essence.

Reaching such a conceptualization needs to make a qualitative work: by understanding all the analysis data from the 2 first levels, the qualitative worker will use their network, and their own personal human experience to overtake the pure belief. They will need to think differently; to break the beliefs, the prejudices about the brand and the markets. Actually they will have to think in a contradictory, not binary way ; they will cross intuition and reason, ideas and feelings, true facts and imaginary facts... they will place emotion inside reason. When sensitivity meets rigor then the good insight will reveal itself, from the brand uniqueness.

No one can give a single definition of what an “insight” or a “brand essence” or an “ultimate idea” is ... we tried to show that such definition is impossible. But we also tried to say what is the necessary research to reach a good concept.

Transdisciplinary is first a human experience for the good of a project.

One consequence : with the Big data era, and the reign of “datascientists” who are organizing the new world trade, we will need experts who will translate data and information in order to understand the trade objects, and to innovate. We will need more and more translators to inspire creation of new concepts, new wording, new symbols; to embody the brand (for instance: logo Nike , Apple, Google, Mc Donald’s ...), new individual and society practices.

But such an ambition could only be satisfied if there is an union between the leaders whose mission is to pilot the brands, within the companies, and that new profile of qualitative researcher, that we described all about human experience and culture. We will need the experts helps, and we will need more and more complex data , that they collect, to contribute and help the change. And we do have that need because our mission, beyond analyzing the consumers, and their needs, is to analyze the problematics, (about the brand or about communication, use, product, service ...), in order to meet in an operative way, to the company marketing and strategical purposes.

As a conclusion about the transdisciplinary behavior that leads our work, we need a symbolic thought , not an intellectual one , to try communicating about what is the function and mission of the qualitative method.

## 6.7 Concluding Remarks: Is Qualitative the Twelfth Camel?

To conclude, I will try to make you understand the role of transdisciplinary qualitative – which role it can play in a world increasingly saturated with objective information. Hoping that your reactions will as well be neuronal as inspirational.

Here’s the story: A father, feeling his end, made arrangements to settle his estate. His herd of camels would be divided among his three sons in the following order: the first son should receive half of the camels, the second son should receive a quarter and the third one a sixth. When the father died, his sons faced a major problem : sharing proved to be impossible, since the herd was exactly eleven camels.

They couldn’t find a solution, so they went to see the khadi, a wise man. After listening to the three sons, the wise man reflected a bit and then finally said: “Take my camel, do your share, and, if God will, you’ll bring it back to me.” Very surprised,

the three sons took his camel and left. However, soon after this, they understood how smart the khadi was: to share twelve camels was very easy – each one received his assigned share – the oldest son received 6 camels, the second son got 3 camels and 2 camels went to the youngest.

Eventually, you see, transdisciplinary qualitative is nothing else than this twelfth camel.

- Qualitative is about going beyond the concrete facts and the measurements, which allows to think out of the box.
- It is a qualitative leap that allows to solve a quantitative problem.
- Qualitative has a symbolic function that helps overcome the deadlocks of rationality.

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## About the Author



**Georges Guelfand** has degrees in Literature, Sciences, Clinical social Psychology, with a background in psychoanalysis.

After creating and managing the qualitative research company INSIGHT, being Associate Managing Director at IPSOS and Managing Director at Synovate France, he is currently President at G&G consulting, and Managing Partner at HAPPY-THINKING PEOPLE France.

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He is author of collections of poetries, articles, and of books: “Les TRIBUS EPHEMERES”, Ed. EPI 1973; “PAROLES D’IMAGES”, Ed. Gaëtan Morin, 2000; “IMAGES WORDS : Projective techniques applied to marketing research”, Ed. Textes & Prétextes 2003; “LES ETUDES QUALITATIVES – fondamentaux, méthodes, analyse, techniques”, Ed. Ems, 2014 .

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# CHAPTER **7**

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## A Case Study Approach to Train Early-Stage Investigators in Transdisciplinary Research

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**T**ransdisciplinary (TD) research is a collaboration in which investigators from diverse backgrounds co-generate ideas. Few successful examples of TD research outcomes have been reported, possibly due to a training barrier. Here, TD trainees present a case study methodology that augmented classic training exercises by removing hierarchical barriers and allowing the practice of TD methodologies. A 30-minute development period was critical for the team to enter the conceptualization phase of TD research, making 90-minute sessions preferable for these exercises. Six sessions over an academic year were necessary for optimum idea formation. Generating buy-in was a challenge, as pressuring potential team members to participate would alter viewpoint equitability. Internal and external enthusiasm grew over the time period. Participation led to sustained collaborations and provided a marketable skillset. This method was low-cost and, likely, generalizable to other institutions. Thus, case study approaches may be effective tools to train researchers in TD interactions.

**Keywords:** transdisciplinary research, postdoctoral fellows, training, case studies.

### 7.1 Introduction

Transdisciplinary (TD) research is a mode of collaboration in which investigators operate outside their disciplines to generate shared research aims [1]. The overarching goal of TD research is to reduce latency periods between discovery of potential therapeutic tools and their implementation in the larger population [2]. The National Institutes of Health have identified the need for TD research and projects

such as the Washington University in St. Louis Transdisciplinary Research on Energetics and Cancer program (WUSTL-TREC) and the Program for the Elimination of Cancer Disparities (PECaD) have been funded to build infrastructures to support these efforts [3-6]. TD research is valuable because it allows a group to collectively: 1) identify complex public health concerns that would benefit from the expertise of a cross-disciplinary team, 2) systematically elucidate causative agents, 3) design multi-level effective interventions/treatments, 4) determine how best to implement such efforts in affected communities, and 5) implement them in a timely manner, while working within the framework of government, business, and advocacy groups [6]. The TD process requires that team members understand and exercise skill sets from other disciplines in which they lack formal training, thus trust must be built among team members across disciplines. Because collaborations across divergent disciplines (e.g. anthropology and molecular biology) are unusual, training scientists in the skills required for TD science is critical.

As observed in a classic reference on organizational change, *The Heart of Change*: “People will think of themselves or of their subgroups first and be protective and suspicious (of others) [7].” For this and other reasons, such as hiring and tenure and promotion, TD research is neither intuitive nor easy. Barriers to TD have been expertly reviewed and include: high labor intensity, lack of interdisciplinary understanding and subsequent conflicts, difficulty for team members to learn a common language, need for shared infrastructure, and the expense of associated costs [8]. Traditional training does not equip scientists with skill sets to mitigate these challenges. These have made examples of effective TD research relatively rare [2], and have highlighted the need to augment traditional training methods [8, 9].

Traditional TD training is based on a multi-mentor apprenticeship model that provides trainees with the following resources: exposure to the process of TD thinking, an expanded scientific lexicon, preparation for career advancement challenges, and protective measures to prevent regression to single disciplinary methodologies [9]. WUSTL-TREC and others have established training programs that achieve these goals. These programs use classical training methodologies such as formal seminars, journal clubs, didactic classes, and individual-project presentations [8, 9]. The training garnered by WUSTL-TREC introduced our team to a knowledge-base and comfort that supported team members’ interactions with others’ disciplines, began to establish a shared lexicon, provided career development preparation, and fostered small collaborations. However, we observed a disconnect between gaining knowledge of the TD process and developing the ability to effectively participate in or lead TD research independently of WUSTL-TREC.

We argue here that a critical gap in TD training is often missing: *the practice of TD research methodologies by assessing public health issues and brainstorming research approaches in a bias-free environment with a team of engaged peers from diverse disciplinary backgrounds*. We suggest that a case study approach using team-based language and mentality is an effective method to practice and train in this skill set. In our initial training, our team of seven postdoctoral fellows and one early career investigator experienced a formality and overlying power structure inherent in a traditional didactic training style that granted authority to the discipline of that session’s leader. This led to disciplinary-specific discussions and inhibited the creative process required for genuine TD idea generation. For example, if the leader was an epidemiologist, then the training session was taught in and flowed from an epidemiological mindset. Additionally, we encountered some aforementioned TD

barriers, such as problems with communication across disciplines. We found that with traditional training methods, the leading discipline was often the final word in conflict resolution, potentially biasing a discussion.

In our case study experience, we initially observed significant challenges to buy-in and idea generation during a case study. Thirty minutes of an introduction period, herein described as “The Thirty Minute Rule”, occurred before true collaborative idea generation. This required that case study sessions last at least 90 minutes. Team members: 1) were fully involved, from case study topic selection to post-discussion reflection, 2) solved problems together and generated TD ideas for future work, 3) developed a shared lexicon, 4) mediated arguments in an open forum, and 5) applied TD-related concepts outside of the allotted discussion times. The results were open communication around a given topic, long-term interdisciplinary collaborations, and development of a valuable skill set. Furthermore, our method was low-cost. Thus, we offer that case study approaches are effective tools to train researchers in TD interactions and may be applicable to other institutions.

## 7.2 Developing the TD Team and Lessons Learned

Here we describe a framework for a trainee-run case study TD training approach, including the steps underwent to launch it, barriers we experienced, and lessons learned.

**1) Assessing institutional preparedness for a TD effort** – Stokols and colleagues succinctly and thoroughly defined characteristics of institutional collaborative-readiness including: institutional support, a wide breadth of disciplines housing trainees, a high degree of prior team cooperation, the availability of convenient meeting places and/or close spatial proximity between collaborators, and the availability of electronic communication tools [8]. Because of WUSTL-TREC, our institution was highly collaborative-ready.

**2) Recruiting advisors** – Organizing members (ECB and LEL) first approached supportive mentors (KHM, GC, SG), who provided ideas and infrastructure. We also sought topical expertise. Dr. Julie Turner (Van Andel Institute) provided insight on leveraging case studies for TD training, structuring the team, and establishing language to foster trust and openness. Dr. Doug Larsen (Washington University) made suggestions on general team structure and training evaluation.

**3) Generating buy-in** – Team members were faced with expending time to an endeavor that might not yield immediate career-building results. Departmental, mentor-based, or other compulsive pressures threatened to negate efforts to build a foundation in which the power structure was equalized. Therefore, buy-in had to be generated at the outset.

Generating initial buy-in was difficult. Fifteen potential postdoctoral fellows and early stage investigators were asked to participate and only five initially accepted. Although we do not know why some declined, opinions expressed included concern about the need for great time and effort, that it was messy with an undefined endpoint, and could potentially expose individual gaps in knowledge. Initial reticence

to participate was also attributed to a lack of clarity about outcomes of the process, difficult travel considerations, and being more distantly related to the existing TREC infrastructure. Trainees who chose not to participate likely also had a range of concern related to career stage, home life, and timing. Our case study team grew from a strong existing WUSTL-TREC infrastructure that supported the time spent on this endeavor, yet we still experienced this barrier. Thus, we suggest that generating buy-in is a challenge that might be experienced by many initiate teams. Interestingly, the testament of the early adopting members fostered increased recruitment; members assured others that use of the TD methodology was being achieved and our final team included eight members. Once a team member participated in one TD discussion session any hesitations lessened, and no attrition was experienced. Validation of the importance of this effort was given by WUSTL-TREC leadership and outside support (e.g. the external advisory board). Thus, non-compulsory buy-in can occur both through initial and secondary recruitment. Conversely, buy-in could not be coerced from uninterested participants. An academic year was required to achieve a well-represented, cohesive team.

**4) Team Composition and Career Stage –** Our final team was composed of seven postdoctoral fellows and one investigator in her first year as assistant professor. Effort was made to minimize overrepresentation of one discipline over others although team members were self-selected. Most initial recruits were trained in the basic sciences (developmental biology, cancer biology, and molecular biology with public health training) or clinical sciences (gynecological oncology). Also, one initial member was a social epidemiologist. As successful discussions occurred, three additional social scientists asked to join (specializing in anthropology, behavioral health, and implementation science). None of the members withdrew from the team during the training.

While our methodology may provide value-added TD training for researchers at all career stages, our experience suggested that three criteria are needed:

- 1) expertise and confidence in one's own field;
- 2) time for additional training activities; and
- 3) an openness to the value and limits of any singular discipline that may be intrinsic or taught from previous training experiences (as was done for our members by the existing WUSTL-TREC and PECaD infrastructures).

Postdoctoral fellows may be particularly amenable to the transformations intended to occur during TD training because of their transitional status. They are at a career stage in which they are determining specific questions and career paths for future work. We found that this transitional state opened our behaviors to new disciplinary perspectives rather than operating from preset rules of thinking; a characteristic necessary for effective TD research. Also, some team members were considering TD research as a potential *de facto* career option. Postdoctoral fellows in the middle of their training had the most flexibility in time and effort and, thus, willingness to dedicate time to the TD training exercises. While this timing-related "sweet spot" may differ from one TD group to the next, it is worth considering in the planning stages in order to maximize the success of TD training groups.

**5) Civility and conflict management –** A commonly cited challenge to TD research is the need for mediation when disciplinary perspectives come into conflict [8,

10]. We addressed this by generating civility guidelines at the outset, which included: 1) respect for all disciplines, 2) sincerity in all comments, 3) allowing respectful requests to table vignettes, and 4) time management. Because the rules were self-developed and enforced, no power structure alterations seemed to be introduced. Importantly, we encountered little need to mediate arguments as trust was built. Regular solicited feedback provided the members opportunity to voice concerns.

Authorship of publications was discussed in advance. It was agreed that the co-first authors had contributed most to the generation of ideas and would retain the major responsibility for synthesizing the chapter; a coin-toss determined their order. Middle authors were ranked alphabetically and the last three authors were the established mentors who supported the effort. This largely reflects the convention of basic science, where the senior author comes last, as opposed to social sciences, where authors are ranked in order of effort.

These characteristics might be best embodied in an early career pool of members (e.g. postdoctoral fellows and early career investigators). When adequately supported by their mentoring teams, postdoctoral fellows may have more freedom to undertake TD training than more senior researchers, who face additional pressures.

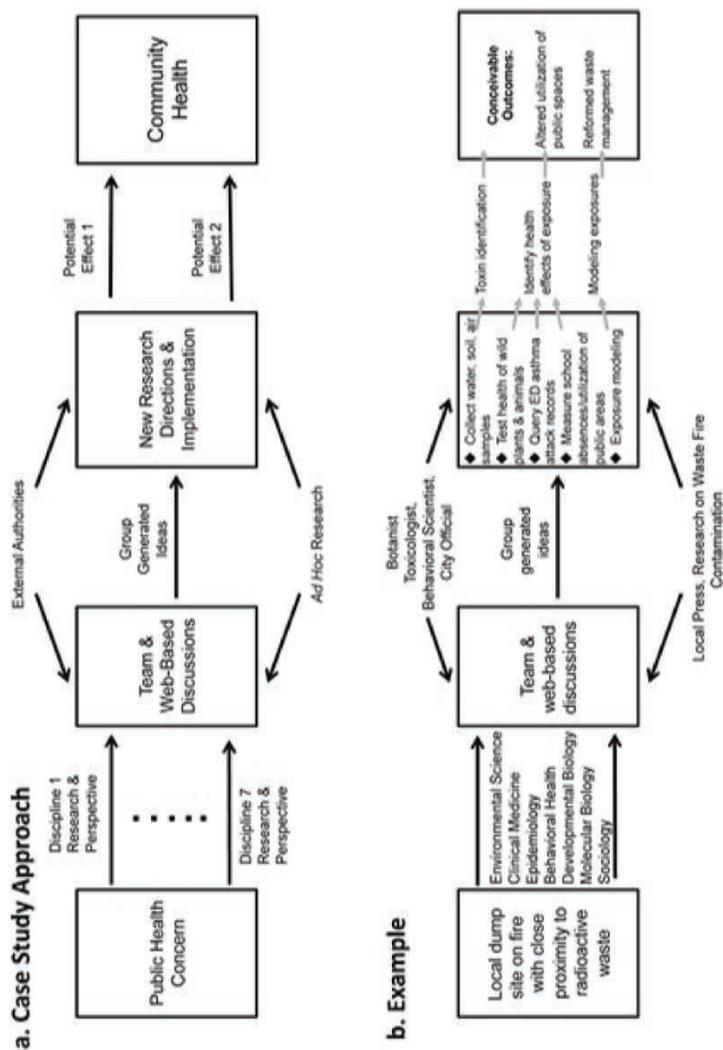
**6) Case study approach** – We chose a case study approach to address the critical gap in TD training (i.e. trainees must practice doing TD). Case study training programs are team-building exercises that allow members to negotiate different problem-solving skills in new ways, while retaining focus within a specific context [11]. As such, case studies allowed our members to apply their expertise to novel concepts and work across disciplines to design approaches and generate solutions within a given study. The initiators of the team brainstormed examples of potential topics for the first two sessions; the team brainstormed the subsequent topics. Our team worked through six case studies that were intentionally broad-based and arose from a common research interest in cancer. Topics ranged from known to unknown etiology (Table 7.1). It was critical to work through several case studies because particular topics organically focused discussions toward certain disciplinary mindsets and methodologies.

Discussions were held monthly for 90 minutes over a period of eight months. Related articles were offered prior to meetings. During the discussion, team members were asked to form hypotheses and design methods to address specific questions, but the conversation was intentionally free flowing with minimal mediation (general discussion flow outlined in Fig. 7.1a). The last five minutes were spent summarizing the discussion.

Throughout the process, the team's communication, trust, and ability to generate ideas increased markedly. For example, the second case study involved prostate cancer disparities in African American men. Few TD ideas emerged from this early discussion. Rather, the team learned to discuss sensitive topics, perform *ad hoc* research during the meeting, and overcome unfamiliarity with working as a team. We also determined points at which external experts were required (outlined in Fig. 7.1a). By the last meeting, many of these initial teamwork based barriers had been resolved. Our final case study was on a local waste site on fire. During this discussion, the team developed several approaches to investigating whether the fire had adverse health effects in the surrounding community. Fig. 7.1b gives an outline of ideas and directions generated from this last discussion. Successful completion of such studies indicating effects on health risks has the potential to inform city planning, waste site

*Table 7.1: Case Study Topics Ranging from Known to Unknown Etiologies*

<b>Case Study Topic Types</b>	<b>Specific Discussion Topics</b>
Examples of collaborative efforts to determine etiology and interventions	Lung cancer and smoking
Existing databases on disease clusters and risk factors	African American disparities in prostate cancer in Michigan
Mechanisms of widespread diseases	Transmission of Human Papilloma Virus (HPV) and cervical cancer
Potential causal agents and disease risk in populations	(1) Social barriers to HPV vaccination rates (2) Substance use and adolescent delinquency
Local public health concerns of interest shared by group members	Local waste fire near nuclear waste dumping ground



**Figure 7.1:** a) A diagram of the intended workflow of a transdisciplinary case study meeting. Team members choose a public health topic, perform discipline-specific research and bring their unique perspective to both in-person and follow-up web-based meetings. During these meetings and subsequent discussions, opinions are gathered from outside experts and additional research on topics is done as needed. Future discussions would determine a workflow for chosen research directions and implementation with the goal of affecting the community in need. This is not based on measurement. b) An example of outcomes from one case study experience.

management, and public policy.

**7) The 30-Minute Rule** – Primary challenges to effective TD research include how to navigate discipline-specific communication styles, understand discipline-specific terms and create a shared lexicon, develop shared research objectives, and jointly conceptualize scientific problems [12]. We sought to navigate these barriers with the case study approach. Previous studies have proposed that TD research transpires in four phases: development, conceptualization, implementation, and translation [12]. This model applied to our case study discussion experiences. The first approximately 30 minutes of each case study was devoted to defining the topic through the lens of each representative field, referred to as the development phase [12]. We found that regardless of topic, a shift in mutual understanding occurred after 30 minutes. At this point, the team entered the conceptualization phase and began to generate novel ideas. We referred to this as the “30-Minute Rule.” As the sessions progressed throughout the year and a shared lexicon was developed, this lag period shortened slightly and the amount of ideas generated in the developmental phase increased. Therefore, we found that team members must persevere through initial communication barriers during the development phase *and be willing to meet for 90 minutes*. We also provided opportunities for team members to continue discussions outside of meetings (e.g. an online forum). Because many classical training methodologies do not require lengthy latency periods before ideas are generated, if unanticipated, this lag period could be demoralizing for new initiate TD case study teams.

**8) Benefits of Participation** – *Long-term collaborations*: An unanticipated finding of this exercise was the development of new cross-disciplinary collaborations between team members. For example, a basic scientist and an epidemiologist initially investigated entirely disparate topics. Yet, a new collaboration arose in which epidemiological expertise was utilized to assess human survey data relating to findings identified in animal models. Survey data would then reciprocally inform the development of future animal studies. Collaborations such as these are unique because the two disciplines came together to generate the research idea and methodology of study, as opposed to one discipline using another to achieve the individual aim of the initiating discipline. Because the research questions were generated together, the scope of the project was broad. Yet the ability to anticipate disciplinary pitfalls added to feasibility of the study. As team members formed long-term relationships during the case study journey, they felt comfortable asking for each others’ expertise and thus anticipated many future collaborations.

*Marketable Skills*: Postdoctoral fellows on the job market found that potential employers favorably viewed their team-based experiences. Indeed, an evolution of attitudes within the team seemed to progress towards open-mindedness over time. Team members exhibited a high willingness to engage with one another so that collaborations matured over the course of the year. By the end of the term, members existed as a team rather than individual experts. At the conclusion of each case study interaction, team members anecdotally reported high feelings of energy and optimism around the topic and ideas generated. The evidence of collaborative skills gained during this process was easily leveraged into leadership and cooperation talking points during interviews.

*Direct measures*: The effectiveness of TD interactions is often measured by co-authorships on manuscripts and grant proposals [13]. As we are only a few months

removed from this experience, these metrics are premature. However, confidence in team members by WUSTL-TREC mentors has increased as reflected by additional TD opportunities offered to our team members including: national meeting oral presentations, manuscript authorships, and investigator status (rather than trainee) on projects and grants.

**9) Plans for Sustainability –** As our team members move on to other positions or encounter career-stage pressures, sustainability of this specific collaboration will be a challenge. However, there is optimism that case study-based TD training initiatives will be sustainable within the WUSTL organization as TD infrastructures could provide a pool of candidates for future teams. We anticipate that the skills developed in the case study process will transfer to future TD endeavors. The case study team has achieved acknowledgement from institutional authorities, which gives it credibility. To ensure sustainability, proof-of-principle recommendations for a problem identified by the team need to be published. Determining whether a team member number ceiling exists for this training methodology is important. Additionally, the case study process will be refined by presenting the project at national meetings.

## 7.3 Conclusions

In conclusion, TD research is an exciting opportunity for teams of researchers to leverage their training differences to shorten the latency between intervention discovery and implementation in the community. TD research has historical barriers that require training to overcome. We suggest that case study based practice approaches can limit inherent power structures that disrupt equitable idea generation that is present in other training forums. The approach described here is particularly well suited to postdoctoral fellows and early stage investigators. We found that a 30-minute development phase was needed before conceptualization and idea generation became prolific. Our case study approach fostered open, authentic communication in a safe environment where team members engaged in problem solving. This technique was low cost, making it a potential training opportunity for all institutions interested in TD research.

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ECB, LEL, KHM, GC, and SG designed the initial group methodology. ECB, LEL, SC, GF, KF, JH, KM, and AR all participated in idea generation, discussion, and group observations. ECB and LEL wrote the manuscript. ECB, LEL, SC, GF, KF, JH, KM, AR, and SG outlined and edited manuscript.

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# CHAPTER **8**

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## A Social Network Analysis Approach to Diagnosing and Improving the Functioning of Transdisciplinary Teams in Public Health

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**B**ackground: The National Cancer Institute's Transdisciplinary Research in Energetics and Cancer initiative is in its second round of funding. Despite increasing agreement that transdisciplinary team-based research is valuable in addressing complex problems like energy balance and cancer, methods for constructing and maintaining transdisciplinary teams is lacking.

*Purpose:* We articulate a method for assessing transdisciplinary teams that relies on social network analysis and using this knowledge to improve their functioning.

*Methods:* Using data from the Washington University TREC site in 2011 and 2013, we demonstrate the use of social network analysis to assess and provide feedback on team functioning.

*Results:* We portray broker functioning in both years. By 2013, the director and co-director had begun to share broker functions with other members. Some brokers fostered communication with less central network members.

*Conclusions:* The information obtained can help to train a new generation of investigators to optimally participate on transdisciplinary research teams.

**Keywords:** transdisciplinary research team, social network analysis, transdisciplinary assessment.

### 8.1 Introduction

Transdisciplinary research gained attention in medicine in the 1990s and early 2000s, when the National Cancer Institute mandated use of the approach in funding initiatives aimed at addressing tobacco use, disparities, and energy balance in cancer. The

Transdisciplinary Tobacco Use Research Centers, Centers for Population Health and Health Disparities, and Transdisciplinary Research in Energetics and Cancer were funded in 1997, 2003, and 2005, respectively. The impetus for their development was a desire to capture the complexity of phenomena like cancer disparities using teams of disciplinary scholars that spanned the social, behavioral, and biological sciences to provide an integrated, holistic approach.

Transdisciplinary research differs from multidisciplinary and interdisciplinary research in the extent to which investigators operate outside the boundaries of their own disciplines to share language, pool knowledge and theories, and develop new methods of analysis. In multidisciplinary research, investigators come together to solve a research problem, but approach it through separate disciplinary lenses. They might, for example, gather at the beginning of a research project with separate but related research questions, collect and analyze data independently, form independent conclusions based upon their separate research questions, and come together at the end of the project to try to make sense of it all. Very rarely do conclusions derived from such a multidisciplinary approach fit together neatly into a coherent whole, and investigators exit the collaboration with no discernible change in their approaches to science. Investigators working interdisciplinarily transfer disciplinary knowledge to one another for the purposes of research, and may share research questions, yet resurrect their disciplinary boundaries when an answer has been found that serves the needs of their root disciplines.

Transdisciplinary research, which Rosenfield defines as exchanging information, altering discipline-specific approaches, sharing resources, and integrating disciplines to achieve a common scientific goal [1], represents the highest degree of disciplinary collaboration. Hall et al. describe its four phases as: (1) development, in which a transdisciplinary team is assembled; (2) conceptualization, during which research questions are refined; (3) implementation, which involves negotiating shared models and goals; and, (4) translation, through which discoveries are translated into change [2]. In this approach, disciplinary scholars transcend and operate outside their own boundaries to achieve synergy, mutually-inform one another's work, and create a new intellectual space in which no one discipline dominates and no way of knowing is privileged over others. The approach has the potential to forge new understandings of major public health problems by breaking down the usual barriers to shared scholarship. Emmons et al. use energetics and cancer as an example of the tremendous inefficiency that occurs when boundaries between the social, behavioral, and biological are rigidly maintained in research, saying "If the primary focus of work in obesity and energy balance is on sociocultural factors, eventually the limits of not considering both environmental and physiologic factors will be realized [3, p. S205]."

## **8.2 The Transdisciplinary Research on Energetics and Cancer Initiative**

The mission of the National Cancer Institute's Transdisciplinary Research on Energetics and Cancer (TREC) initiative, which includes multiple sites around the country, is to foster collaboration across multiple disciplines and projects to cover the spectrum from the biology, genetics, and genomics of energy balance to social and behavioral influences on physical activity and nutrition, weight, energetic, and cancer risk [4]. This collaboration is meant to occur within and across TREC sites.

Currently in its second five-year round of funding, the four TREC sites are the University of Pennsylvania, Washington University, the University of California-San Diego, and Harvard University, with a Coordination Center at the Fred Hutchinson Cancer Research Center in Seattle. The TRECs also have a mission to train new and established investigators to carry out integrative research on energetics and energy balance and cancer.

Each TREC has approximately four research projects and a number of cores to support their work. In addition, the initiative funds a number of within- and cross-TREC developmental research projects that are selected from applications solicited once a year by the TREC Steering Committee, which is made up of the principal and co-principal investigators of the TREC sites and the Coordination Center. The developmental projects are meant to extend the research of the TRECs into new areas of discovery and translation.

### **8.3 Evaluating Effectiveness within and Across TREC Sites**

Considering the group of TREC investigators as a social network, or a social entity made up of a number of actors, allows the group's functioning to be analyzed in its entirety as well as the dyadic relationships between its members. The assumption is that stronger and more frequent communication and the formation of new cross-disciplinary ties will better foster advances in the science of energy balance and cancer. It is assumed that investigators will at minimum be aware of the mission of their TREC site and of the broad objectives of its research projects. Optimally, they would be conversant in one another's work through exposure during regularly-scheduled team meetings and through the co-mentoring of trainees [5]. At the Washington University TREC site, for example, postdoctoral fellows select three mentors that span disciplines from a menu of faculty who have agreed to participate in the training program.

Investigators might communicate directly with one another, as in the case of project and core leaders, or through members of the team who serve as brokers of information about the TREC site as a whole and its shared research agenda. Brokers are defined as network members who link to otherwise unconnected members of the network [6]. They play important roles in linking members by serving as go-betweens in terms of information transfer and day-to-day communication of research activities and findings.

Brokers might be the principal mode of communication for investigators who are less centrally involved in projects and cores. Inevitably, some researchers are less involved than others, especially those whose academic responsibilities are less-well covered by TREC funding. A challenge of transdisciplinary sites is to engage investigators who are less central to the TREC funding mechanism and those who might be dispersed due to off-site clinical duties. Bringing less well-integrated investigators into communication with the team as a whole ensures the maximization of TREC's scientific discovery and translation. One example of how this might occur is when a broker is able to convey information and ideas about potential cross-site or cross-project developmental projects to other members of the network.

More ties between investigators signify greater communication within a network. The principal way of evaluating this quality is by measuring the density of social

network ties, defined as the number of actual ties between network members compared to the number of potential ties. Denser networks suggest faster propagation of information and greater group cohesion [6]. Also, individuals who conduct more information tend to be more productive in terms of research goals and objectives [7].

Despite increasing agreement that transdisciplinary research is a valuable approach to addressing complex problems like energy balance and cancer, methods for constructing and maintaining effective transdisciplinary teams are lacking. In the present chapter, we articulate a method for diagnosing transdisciplinary teams' strengths and weaknesses that relies on social network analysis, and using this knowledge to improve their functioning. With data from the Washington University Transdisciplinary Center for Energetics and Cancer at two time points (2011 and 2013), we demonstrate how social network analysis was used to assess and provide actionable feedback on the strengths and weaknesses of the team. We then discuss how the information obtained might be used to train a new generation of investigators to optimally participate on transdisciplinary research teams.

## **8.4 Methods**

### **8.4.1 Study Sample**

Participants in the study were investigators involved in the TREC research site at Washington University in St. Louis, including postdoctoral trainees. Here we report on 24, 31, and 31 investigators from Washington University who were involved in the social network analysis research project in 2011, 2013 and 2014, respectively.

A list of investigators was developed by the TREC Steering Committee, and after receiving IRB approval, each was sent a letter inviting them to participate along with a copy of the social network survey. The survey was sent during the first months of the second round of funding for the TREC sites, for the purpose of establishing a baseline measure of ties. None of the sites funded during the first round of TREC funding was refunded, thus all sites were new to TREC. The survey will be re-sent yearly throughout the five years of funding to assess the increase in density of social network ties over time. In this chapter, we report on data from the first three years of data collection, using data from the Washington University site only. Note that the number of respondents for the survey is less than the network size, or the total members in the network (see Table 8.1). The number of survey respondents, who are the primary actors in the network, is 20, 20, and 19 in 2011, 2013, and 2014, respectively. The difference between the respondents and the total network actors is due to the secondary actors who are included in the network because they were designated by respondents as a link but did not themselves respond to the survey. Thus we do not know about the relationship among the secondary actors. We address this because the network density can be sensitive to the number of respondents rather than the network size, which often makes it hard to fairly compare the longitudinal social network data due to different set of respondents each time point.

**Table 8.1:** Response Rate and Network Size for the Washington University TREC site in 2011, 2013 and 2014

	2011	2013	2014
<b>Number of invited</b>	<b>25</b>	<b>25</b>	<b>22</b>
<b>Number of respondents</b>	20(80%)	20(80%)	19(86%)
<b>Professor</b>	9	9	8
<b>Associate Professor</b>	1	4	3
<b>Assistant Professor</b>	6	5	5
<b>Research Associate</b>	2	1	1
<b>Other</b>	2	1	2
<b>Network size (N)</b>	24	31	31

## 8.5 Measures

### 8.5.1 Collaboration Network

The survey included the names of all TREC investigators and asked respondents if they currently worked with, or had worked with prior to TREC, any investigators on the list in any of six situations:

1. on a study or grant;
2. on a co-authored publication;
3. on a co-authored presentation;
4. in mentoring or training;
5. on a committee or work group; or,
6. in any other activity.

For the purposes of the present study, participants were considered to have worked with another investigator if they indicated that they currently were collaborating on any of the six listed activities. The percent of collaboration types is summarized in Table 8.2.

### 8.5.2 Discipline

Investigators were asked to choose from a list of 37 academic disciplines the one which best characterized the primary disciplinary perspective of their work. For purposes of analysis, these responses were collapsed into eight disciplines (see Table 8.3).

### 8.5.3 Density

Density is the proportion of ties that exist among all possible ties (also called edges). From Table 8.4, we can see the density remains the same or slightly decreases over time. It is worth noting, however, that the density measure is sensitive to the growth of network size and the change of respondents. As a network gets larger, the density

**Table 8.2:** Nature of Collaboration for the Washington University TREC site in 2011, 2013 and 2014 (unit: % of the total ties in each year)

Year	Grant	Co-authored Publication	Co-authored Presentation	Mentorship	Committee	Others
2011	37.66	18.18	11.69	31.17	35.71	3.9
2013	62.5	28.8	17.93	30.43	36.96	5.98
2014	43.53	42.94	28.82	38.82	38.82	7.06

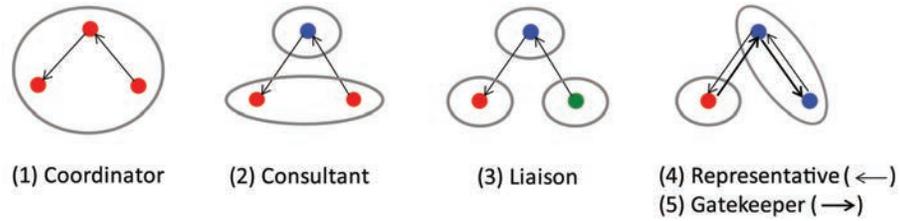
**Table 8.3:** Number of Investigators by Disciplines for the Washington University TREC site in 2011, 2013 and 2014

Categories of Disciplines	2011	2013	2014
2. Statistics & System	4	4	4
3. Social/Behavioral Science	5	6	6
4. Epidemiology	4	5	5
6. Medicine	8	10	10
7. Nutrition/Metabolism	1	3	3
8. Public Health Practice	2	3	3
<b>Total</b>	24	31	31

**Table 8.4:** Network Density for the Washington University TREC site in 2011, 2013 and 2014

	Network size	No. Respondents	All possible edges	No. edges	No. triangles	Density
2011	24	20	276	72	79	0.26
2013	31	20	465	109	158	0.23
2014	31	19	465	96	119	0.21
2014b	31	23	465	104	148	0.22

tends to decrease since the number of possible edges is  $\frac{n^2-n}{2}$  and this grows faster proportionally than the number of relationships. Also, losing one member, especially if that person is an active collaborator may result in losing all of that member's related ties, thus reducing overall density. For this reason, it is prudent to look at the absolute number of edges in the network (Table 8.4). We see the network expanded the most in 2013, with 109 ties compared to 72 ties in 2011 and 96 ties in 2014. The active collaboration in 2013 is partly because there was considerable



**Figure 8.1:** Illustration of the Five Brokerage Types in Directed Network. Colored dots are actors where the top point is the broker. Ellipses are the discipline boundaries.

grant related work in 2013 (Table 8.2). Although the overall density decreased in 2014 compared to previous years (Table 4), the collaborative work represented by the number of co-authored publications and presentations increased in 2014 (Table 8.2). In addition, we attempted to recover 2014’s missing data for the respondents who responded the survey in 2013 but did not response in 2014 by assuming that the network relations of these members remained the same through 2013-14. We add this missing imputation result in 2014b in Table 8.4. The improved number of edges in 2013 and 2014 (2014b) compared to 2011 indicates general improvement of collaborative functions within the Washington University TREC site. We further investigate how the characteristics of network transform over time.

## 8.6 Analysis

Social network analysis was used as the principal mode of analysis in the present study. We considered the investigators of the Washington University TREC site who participated in our survey as the network actors in our analyses. We define *brokers* as individuals who collaborate with two other network members who do not collaborate with one another, and assume mutual rather than unidimensional collaboration.

Gould and Fernandez [8] define brokerage relations based on ordered triples of actors in a sequence of communication. A coordinator broker connects two members of the same discipline of which the broker is also a member, while a consultant broker connects two members from the same discipline of which the broker is not a member (see Figure 8.1). A liaison broker connects two network members from different disciplines and is not a member of either of those disciplines. A representative broker connects a member of the broker’s own discipline to a network member from another discipline. The gatekeeper broker involves the same three types of members (i.e., the broker and one member each from the same and a different discipline) as in a representative brokerage, but differs in the direction of information flow. The gatekeeper broker controls the flow of information from the outside-discipline member to the member of the gatekeeper’s own discipline. In other words, the gatekeeper broker decides whether to grant access to a member from his own discipline, which effectively would cut that member off from network information. Because a representative and a gatekeeper broker are indistinguishable from one another in a

mutual network [6, 9], we merged them into one category, which we designated as representative/gatekeeper.

For any ordered triple of actors  $i, j$  and  $k$ , the situation in which  $j$  is a broker between  $i$  and  $k$  is denoted by the symbol  $ijk$ . In other words,  $ijk$  means  $i$  is tied directly to  $j$ ,  $j$  is tied directly to  $k$ , and  $i$  is not tied directly to  $k$ . Then, an actor  $j$ 's total brokerage activity in a network with  $N$  actors is defined by measuring the number of ordered pairs  $(i, k)$  in the network for which the condition  $ijk$  holds. We modify the brokerage measure by a set of subgroups. The first type is denoted by  $m_i = m_j = m_k$  since all three actors belong to the same group. Similarly, the second type of relationship is described by  $m_i = m_k \neq m_j$  showing that two endpoints  $(i, k)$  belong to the same group while the broker  $j$  is an outsider, and so forth in other types. Then, an actor  $j$ 's coordinator brokerage score, named as  $w_{Ij}$ , is defined as follows:

$$w_{Ij} = \sum_i^N \sum_k^N w_I(ik), \quad (i \neq j \neq k),$$

where  $N$  is the number of actors in the network, and  $w_I(ik)$  equals 1 if  $ijk$  is true and if  $m_i = m_j = m_k$ , and 0 otherwise. The other subtypes of brokerage can be computed following the same principle and named as  $w_{Oj}, b_{IOj}, b_{OIj}, b_{oj}$ , corresponding to consultant, representative, gatekeeper, and liaison, respectively. The notation  $w$  is used for the coordinator and consultant brokerage score denoting *within* group roles because two endpoints  $(i, k)$  belong to the same subgroup. On the other hand, the representative, gatekeeper, and liaison brokerage scores are notated by  $b$  because these are *between* group brokerage roles with two endpoints belonging to the different subgroups. Consequently, any actor  $j$ 's total raw brokerage score  $t_j$  can be calculated by the summation of the raw scores from these five subtypes. This raw measure is useful if the researcher is interested in the number of brokerage relations that an actor is capable of mediating. On the other hand, when the central issue is the degree to which the actor actually controls brokerage relations in the network, then the appropriate measure is the partial score  $t_j^*$ , which can be computed analogous to  $t_j$  but divided by  $g_{ik}$ . For example,

$$w_{Ij}^* = \sum_i^N \sum_k^N w_I(ik)/g_{ik}, \quad (i \neq j \neq k, \quad g_{ik} \neq 0),$$

In which  $g_{ik}$  is the number of two-step paths between  $i$  and  $k$ . Our analysis used  $t_j^*$  because our interest lies in the degree of each actor's contribution as a broker in the network rather than his or her capacity as a broker. The network as a whole can be characterized in the same terms. This is referred to as a global brokerage measure of the network and defined as

$$W_I = \sum_j^N W_{Ij}.$$

We computed a standardized brokerage score for each Washington University site network member, which enables us to directly compare brokerage scores across the years [6]. The standardized scores ( $\beta$ ) are computed by  $\beta = (b - \mu_b)/\sigma_b$ , where  $b$  is any of the brokerage scores defined above,  $\mu_b$  is the expected value of  $b$  and  $\sigma_b$  is

the standard deviation of  $b$  under the null model. It is reasonably assumed that the standardized brokerage scores of actors follow the standard normal distribution for sufficiently large networks (about 15 actors for global scores, 30 for individual scores) [8]. Thus a higher positive score for an actor means that the actor occupies more brokerage positions than actors with lower brokerage scores. A negative extreme score, however, means that the actor avoids being a mediator in the network or prefers to operate independently. We used a 0.1 significance level, which further helped us to determine whether or not a network member was a broker. Our criterion for deciding if a network member was a broker was whether the investigator's standardized brokerage score was greater than 1.64, the approximate value of the 95th percentile point of the standard normal distribution. The brokerage scores were calculated in the same way for each type of brokerage. We used the R package 'sna' [10] to derive functions for all brokerage scores.

In principle, we reject the null hypothesis of a random network when we observe too many or small number of actors at extremes ( $>1.64$  or  $<-1.64$ ). This is done by comparing the number of members whose scores fall at the ends of the distribution to what we would expect in a random network. For example, in a completely random network with 31 actors, only 5 percent of the actors (1.6 actors) should have a high positive brokerage score ( $>1.64$ ).

## 8.7 Results

We observed more Washington University TREC site network members in 2013 and 2014 with brokerage scores that were higher than 1.64 (i.e., higher than expected), which led us to reject the null hypothesis for 2013 and 2014 (see Table 8.5). We could not, however, reject the null hypothesis for 2011. We took this to mean that while the Washington University TREC network was not particularly brokerage-oriented in 2011, it had become so by 2013 and 2014. This observation is consistent with the global measure in Table 8.6. This table displays global measures of brokerage for all brokerage types and for brokerage in general. The 2013 total score is statistically significant at the 0.05 level (score  $> 1.96$ ). By 2013, pairs of actors were more likely to be brokered than they were in 2011 or than they would be in a random network. The liaison role's relatively high global score (1.85) in 2013 suggests that actors in the system are more likely to participate in brokerage activities in which all belong to different disciplines. The high liaison score of the global measure is also related to the high liaison roles of the PI and Co-PI (Table 8.7). The 2014 global brokerage score is statistically significant, especially for representative/gatekeeper brokerage (2.28). From Table 8.5, we see that the members 1 and 31 contribute to this brokerage role in addition to the PI and Co-PI.

Figure 8.2 portrays the Washington University TREC site network, with nodes sized according to total brokerage score and colored according to disciplinary category. In 2011, the principal investigator (PI), an epidemiologist, and the co-principal investigator (Co-PI), a social scientist, were the two primary brokers in the Washington University TREC network. By 2013, more brokerage relations are observed among other network members. Table 8.5 lists broker relations for each year according to a criterion of  $>1.64$ . For example, member 1 acted as a coordinator and representative/gatekeeper for the discipline of Medicine in 2013. In 2014, this brokerage role is more solidified for some members: member 1 remains as a repre-

**Table 8.5:** Brokers by a Criterion that Standardized Brokerage Scores > 1.64 for the Washington University TREC site in 2011, 2013 and 2014

Brokerage Relations	Investigator Id		
	2011 (N=24)	2013 (N=31)	2014 (N=31)
1. Coordinator	17, 21, 23	1, 5, 6, 17, 21, 31	5, 17, 21, 31
2. Consultant	17, 21	17, 20, 21	17, 21, 28
3. Liaison	17, 21	17, 21	17, 21, 28
4. Representative/Gatekeeper	17, 21	1, 17, 21, 31	1, 17, 21, 31

**Table 8.6:** Global Brokerage Measures for the Washington University TREC site in 2011, 2013 and 2014

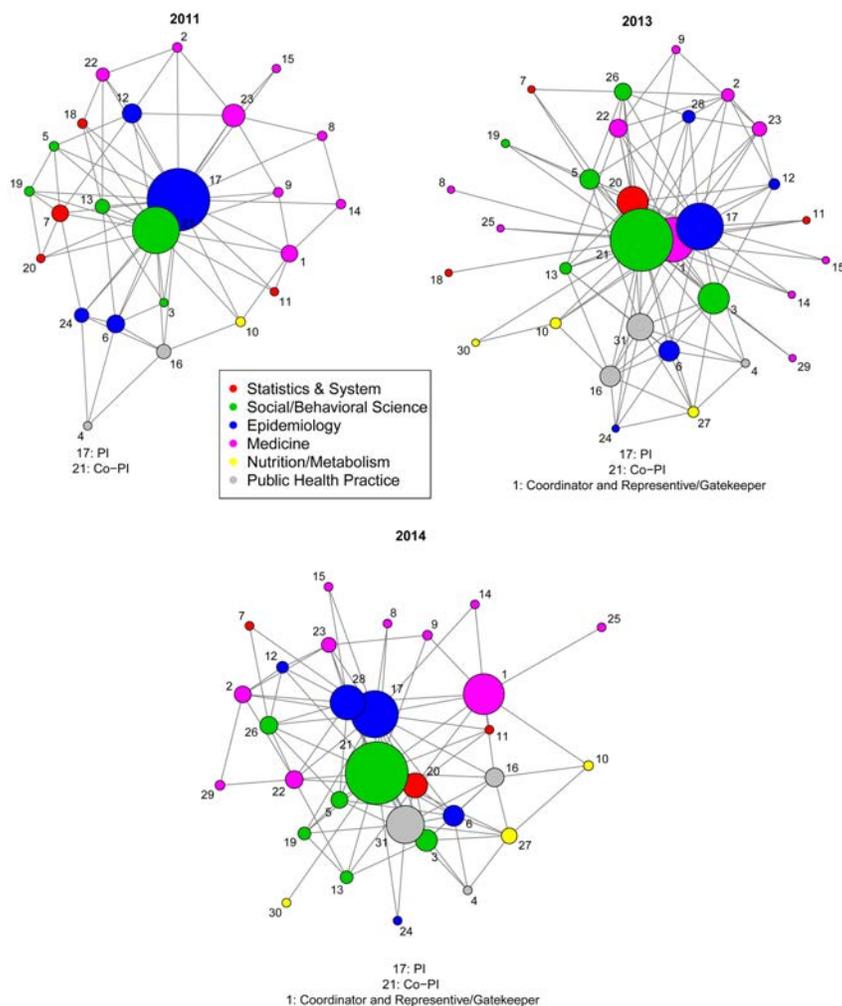
Brokerage Relations	Standardized Global Brokerage Score		
	2011	2013	2014
1. Coordinator	1.46	1.57	1.35
2. Consultant	-0.71	0.76	0.13
3. Liaison	1.1	1.85	0.45
4. Representative/Gatekeeper	1.23	1.58	2.28
<b>Total</b>	1.26	2.2	1.49

**Table 8.7:** Standardized Brokerage Scores for Principal Investigator (PI) and Co-principal Investigator (Co-PI) for the Washington University TREC site in 2011, 2013 and 2014

Brokerage Relations	PI			Co-PI		
	2011	2013	2014	2011	2013	2014
1. Coordinator	6.06	6.3	7.2	7.72	10.75	8.58
2. Consultant	16.64	6.0	11.68	3.89	25.54	11.61
3. Liaison	24.06	9.85	14.64	10.08	34.88	18.62
4. Representative/Gatekeeper	11.88	5.81	7.08	9.58	18.65	15.58
<b>Total</b>	25.78	10.98	16.09	12.99	37.96	23.28

sentative/gatekeeper, member 28 is a consultant and liaison, and member 31 is a coordinator and representative/gatekeeper.

Standardized brokerage scores for the PI and Co-PI for all brokerage types can be



**Figure 8.2:** Network Plot of the Washington University TREC site in 2011, 2013 and 2014. The number in nodes is the unique id of investigators, and the node size indicates the total brokerage score of the investigator. The nodes are colored by different disciplines. The nodes of 17 and 21 are downsized than actual brokerage score for visual convenience. In 2011, PI and Co-PI are the main brokers in this network. In 2013 and 2014, more brokerage relations exist (see also Table 8.5).

found in Table 8.7. In general, both the PI and Co-PI have higher brokerage scores than other network members across all four brokerage types, indicating that their

intermediary roles as a coordinator, consultant, liaison and representative/gatekeeper are all crucial in this network. Their roles as liaisons are especially salient in the network, linking all disciplinary categories. It is also the case that the broker relations of the PI and Co-PI changed through the years. The Co-PI's broker relations were substantially higher in 2013 than 2011, as seen by the higher total brokerage score for the latter year (see Table 8.7), and decreased a bit in 2014. Meanwhile, the PI tended to distribute his brokerage role to other members by 2013-14, evidenced by a lower total brokerage score in 2013-14 than 2011 and the increased numbers of brokers in 2013-14 (see Table 8.5). It is worth noting that a decrease in brokerage score does not necessarily mean a decrease in collaborative relations. It also can indicate an increase in triangle relations (complete transitivity).

Another natural way to measure brokerage is through the centrality measure known as *betweenness* [11],  $g(w) = \frac{\sum_{s \neq w \neq t} \sigma_{st}(w)}{\sigma_{st}}$ , where  $\sigma_{st}(w)$  is the number of "paths" from node  $s$  to node  $t$  that pass through node  $w$  and  $\sigma_{st}$  is the number of shortest paths between them. We computed the betweenness for all investigators and found that the correlation between the betweenness and the brokerage score was extremely high (0.99) in all years. In fact, betweenness and brokerage scores are similar in their abilities to measure the extent to which each actor controls the network as a broker. The difference is that betweenness is based on counting the shortest paths of a pair  $(i, k)$  that the actor  $j$  lies on, which can include more than two-steps relations, whereas the total brokerage score only regards a two steps brokerage process. Thus it is not surprising two measures are empirically close in a small network like ours. We include both, with the knowledge that the brokerage score provides a more precise measure of the kinds of brokerage and clarifies the characteristics that each actor may perform.

Representative brokers are in a better position to link people who might otherwise not link with one another as a result of being in the same discipline. These individuals may therefore be more translational in their research. It is interesting to note that in all years, network investigators from the medical discipline on the whole had the fewest network ties. Yet, when the representative brokerages were considered, it became clear that one network member from medicine linked the medical investigators to other members of the network. Coordinators, who broker relationships in which all members are from the same discipline, arguably may be seen as less translational. We intend to follow this pattern over time to see if it is replicated.

## 8.8 Discussion

A number of findings from our use of social network analysis to assess and provide actionable feedback on the functioning of the Washington University TREC team suggest ways in which the transdisciplinary functioning of the group can be improved. Understanding the patterns and types of brokers within the TREC social network allows plans to be developed for increasing the connectedness of investigators, especially those who have not been well integrated into the network. This raises the likelihood that their perspectives will add to the team's ability to capture the complexity of energy balance and cancer.

Identifying who serves as liaison brokers suggests ways of fostering engagement through communication and training. Likewise, identifying consultant brokers suggests a way of linking members of the same discipline within the network who pre-

viously were unlinked. Information on coordinator brokers suggests another way of organizing disciplinary sub-networks within the network, with the goal of better integrating them into the network. Similarly, identifying representative brokers provides a first step toward connecting disciplinary sub-networks of disciplines with the network as a whole.

We found that investigators from the medical discipline had the fewest ties to the TREC network, which was rendered less worrisome when we determined that they were being linked to the network through one network member from medicine who leads one the TREC's four research projects (see Figure 8.2). This investigator plays a valuable role in transmitting information and ideas between medical discipline investigators and other network members.

We also found that although the PI initially fulfilled the most brokerage functions, by the second time of data collection, he had begun to share these functions with the Co-PI and other network members, thus minimizing burnout and helping to ensure the flow of communication among TREC site investigators. That the two administrators of the site held complementary roles in terms of integrating investigators within the site maximized communication and helped to ensure that information was flowing, thus optimizing the development of new research questions, methods, and analyses that mark the success of transdisciplinary research.

### 8.8.1 Implications for Process and Training

The pattern of brokerage across the site suggests areas of focus to ensure optimal transdisciplinary communication while conserving valuable resources, not the least of which is investigator time. This occurs by virtue of providing information to help administrators determine the frequency and structure of team meetings in a way that balances the benefits of the exposure to ideas from the full range of disciplines with the cost of scheduling and implementing meetings. For example, we now know the benefit of including our representative broker from medicine in wider team meetings, because her ties to other network members from medicine will help to ensure that they receive information from other disciplines.

Likewise, analysis of brokerages suggests how to optimize team functioning by training investigators to assume certain broker roles. In our example, medical investigator team members were less likely to be engaged with members from other disciplines, perhaps because of their clinical duties and physical location at sites outside the medical campus. Our social network analysis let us realize the importance and viability of having a medical investigator serve as a representative broker role. Had one not been available to serve the role, it would have been prudent to train someone to assume that position. Other brokers, such as liaison brokers, connect investigators from outside their own discipline with members from other disciplines, in other words, they foster transdisciplinary groupings of investigators. This is essential for achieving the benefits of transdisciplinary research. Network analysis allows a team to determine whether the broker function is being filled and if so, how successfully. If neither administrators nor other investigators are assuming the role, a member or members can be trained in the liaison broker role.

We report only for the Washington University TREC in the this chapter, in order to investigate one network in depth. We will report on data from all five TREC sites (i.e., the University of Pennsylvania, the University of California-San Diego, Washington University, Harvard University, and the Coordination Center at

the Fred Hutchinson Cancer Research Center) for the years reported in the present paper and for 2015. It is possible that the picture seen for Washington University will change when data from other sites are included and another year of data is added.

## 8.9 Conclusions

Transdisciplinarity and team science have increasingly been recognized for their benefit in advancing new scientific discoveries and moving those discoveries to translation into patient care and community health. Yet, how to achieve the benefits of transdisciplinary research is neither intuitive nor based upon clear guidelines from funders. Social network analysis that considers broker functions on research teams provides a means of assessing team functioning so that changes can be implemented to maximize functioning. These changes, based on the flow of information, allow mid-course corrections to be made rather than second guessing when teams are not functioning as planned.

## Acknowledgments

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# CHAPTER **9**

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## Understanding Global Cancer Disparities: The Role of Social Determinants from System Dynamics Perspective

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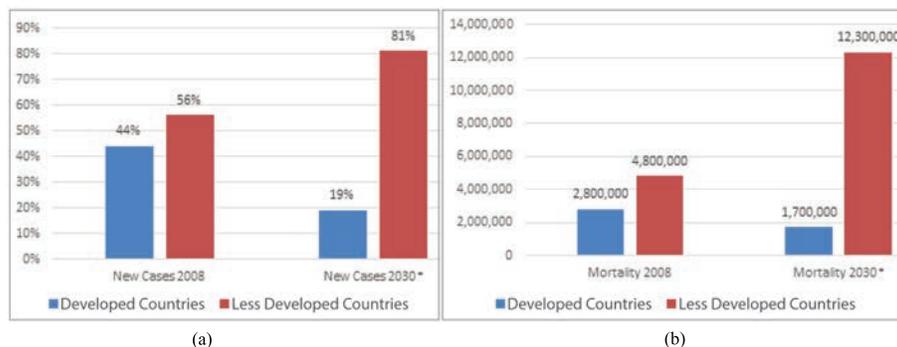
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**Background:** *In 2012, almost 57% of all cancer cases and 65% of cancer deaths occurred in low-and middle-income countries. If the current trend continues, the burden of cancer will increase to 22 million new cases annually by 2030, with 81% of new cases and almost 88% of mortality occurring in less developed countries.*

**Methods:** *A qualitative review of the literature was conducted. This included a systematic search of eight electronic databases namely, PubMed, Academic Search Premier, CINAHL, Applied Social Sciences Index, EMBASE, SCOPUS, Cochrane and PsycINFO. The reference list of articles retrieved were also thoroughly searched. Inclusion criteria were studies that addressed global health, cancer disparities and global or economic development.*

**Results:** *Thirty-one articles were identified that met the eligibility criteria. Results were synthesized in the form of a system dynamics causal loop diagram or map which led to identification of eight major stocks or system variables. These included children and adult population, overall population health, pollution, quality of healthcare delivery, quality of neighborhood and built environment, social and community cohesiveness, healthy and social norms and attitudes, and literacy level. Based on this, a dynamic hypothesis of global health cancer disparities was developed. The causal loop diagram showed the role of multiple interacting feedback mechanisms as explanations for trends in global health cancer disparities and the underlying consequences.*

**Conclusions:** *Addressing these determinants of health requires an effective dynamic approach to improving global cancer health. Application of a systems thinking methodological approach has the potential to provide new understanding to how global devel-*



**Figure 9.1:** (a) Estimated new cancer cases for 2008 and 2030, (b) Estimated Cancer Deaths for 2008 and 2030

opment trends in combination with global health efforts to improve population health could shift cancer disparities and burden associated with the disease.

**Keywords:** Global health, cancer disparities, social determinants, system dynamics, systems science, global development, economic development.

## 9.1 Introduction

Cancer is the leading cause of death globally, costing the world economy almost one trillion dollars per year [1]. The total economic impact of premature death and disability from cancer worldwide was \$895 billion in 2008, 20% higher than heart disease [1]. According to the International Agency for Research on Cancer, 8.2 million cancer related deaths occurred globally in 2012, compared with 7.6 million in 2008 [2]. Of these, almost 57% of all cancer cases and 65% of cancer deaths occurred in low-and middle-income countries (LMCs). If the current trend continues, the burden of cancer will increase to 22 million new cases annually by 2030, an increase of almost 70% from 2008 [2]. Worldwide cancer deaths are also projected to continue to rise to approximately 13.2 million in 2030 due to population growth and aging [3-6]. The diagrams show the global distribution of new cancer diagnoses and projected deaths for 2008 and 2030 (see Figure 9.1 a & b).

Cancer mortality in most developed countries has been decreasing since the mid-1990 due primarily to advances in biomedical technology leading to an increase in early diagnosis and treatment [7,8]. However, the impact on individuals, communities and populations constitutes a major threat to advancement in many less developed countries, due to lack of access to healthcare services, poverty, and education, all of which increases morbidity and mortality from the disease [1,2,9,10].

Given the complex set of interactions of social determinants underlying global health, especially cancer disparities, social and economic development, as well as population health, new methods are needed to better identify and understand the potential feedback mechanisms driving long-term trends in development, social determinants, and cancer deaths. One such method, system dynamics, studies complex,

nonlinear feedback systems and their dynamics [11]. Prior work exists on specific diseases and healthcare delivery, but there has been little application of system dynamics to global cancer disparities.

### 9.1.1 Aim

The objective of this work was to develop a conceptual framework in the form of a system dynamics causal map based on the extant literature of the systems underlying trends in global cancer disparities.

## 9.2 Approach and Methods

### 9.2.1 Systematic Review Process

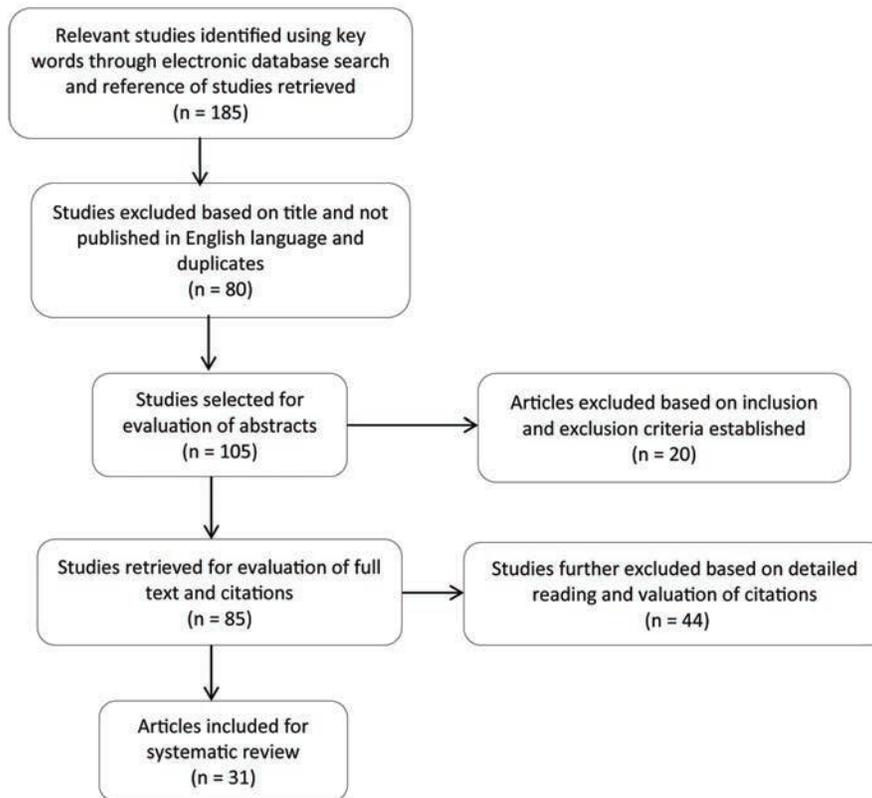
A qualitative review of the literature was conducted. This included a systematic search of PubMed (1951-2013), Academic Search Premier (1984-2013), CINAHL (1937-2013), Applied Social Sciences Index and Abstracts (1987-2013), EMBASE (1947-2013), SCOPUS (1982-2013), Cochrane (1993-2013) and PsycINFO (1987-2013) databases using the keywords: “global health”, OR “economic development” OR “human development” AND “cancer “disparities” OR “inequalities”, AND “social determinants” OR “social determinants of health” AND “system dynamics” “systems thinking” OR “system science”. In addition, secondary references were retrieved within the reference lists of publications that were included for review. There was no limitation of publication date in the search; however, the earliest eligible article was published in 1993. Inclusion criteria were studies that addressed global health, cancer disparities and global or economic development and published in the English language. Studies not meeting these criteria were excluded.

## 9.3 Results

### 9.3.1 Global Cancer Disparities Concept Model Scope and Subsystems

A total of 183 original full-text articles were found across the electronic databases mentioned earlier, and 2 additional studies were identified through references of articles retrieved. Eighty studies that were either duplicates, and not published in the English language were further eliminated. Based on the inclusion and exclusion criteria established 20 studies were removed. Full screening was performed on the remaining 85 studies. After thorough review 44 studies were further excluded. A total of 31 [4-6,8,10,12-37] studies were considered eligible and used in the development of model scope and causal loop diagram or map. The flow chart shows the summary of criteria used for inclusion of eligible studies (see Figure 9.2).

The resulting model scope consists of four main sectors or subsystems: population health, development, healthcare system and neighborhood and built environment (see subsystem diagram in Figure 9.3). The model scope and subsystem diagram (Figure 9.3) illustrates how healthcare, environment, governmental policies and overall level of development collectively shape and influence population growth, inequalities in healthcare and health outcomes.



**Figure 9.2:** Flow Diagram for literature search results and application of eligibility criteria

Countries in Sub-Saharan Africa are already struggling to control the widespread of many communicable/tropical diseases facing them. The emergence of non-communicable diseases such as cancer is likely to exacerbate the public health problems. The population health subsystem (Figure 9.3: top left) captures the number of adults, children, new births as well as mortality and morbidity from cancer and other diseases. The level of population health is influenced by the country's economic development and resources available to promote better quality of living. For instance, lower mortality from diseases will lead to significant increase in workforce of a country thereby improving economic performance. Additionally, healthy workforce can create incentives for more business opportunity for investment.

The endogenous factors affecting development sector (Figure 9.3: top right) include: gross domestic product (GDP), political stability, corruption, income and prevailing social condition of a country. One of the responsibilities of government is to ensure stable economy, growth and development. Subsequently, governmental policies and regulations in a country can affect investment, employment and economic

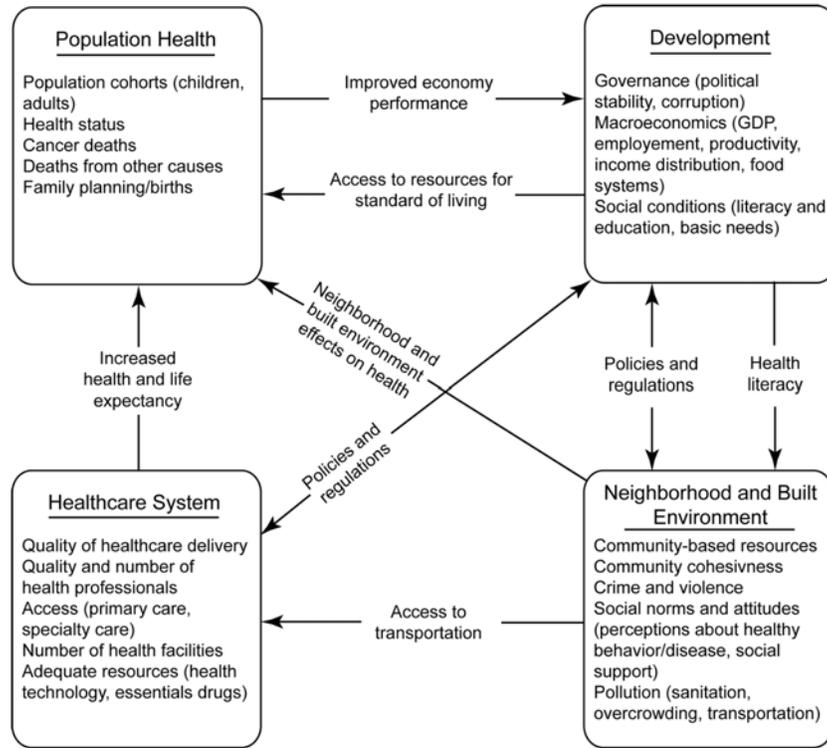


Figure 9.3: Model scope and subsystem diagram

growth. Political instability for instance, can contribute to a country’s underdevelopment through adverse effects on worker productivity, income distribution, disruption in healthcare delivery and negatively influences economic performance. Similarly, given the evidence that socioeconomic status highly affects health and health affects income, higher economic development, can translate into higher incomes for workers leading to improvement in the country’s healthcare development and infrastructure, people’s well-being, and the environment.

The healthcare system sector (Figure 9.4: bottom left) captures factors contributing to increased health and life expectancy of the population. A strong healthcare infrastructure is essential to meeting the healthcare needs of the population as well as reducing high costs associated with premature preventable deaths. Lack of adequate healthcare infrastructure such as essential drugs and access to primary care and specialty care are the major barriers to effective care delivery in most developing countries. To effectively meet the growing health needs and reduce health disparities between developed and less developed countries, it is important for governments to invest in modern healthcare technology and implementation of policies that support individual and community health.

Neighborhood and the built environment subsystem (Figure 9.3: bottom right) shows prevailing factors in the built environment and their subsequent contribution to

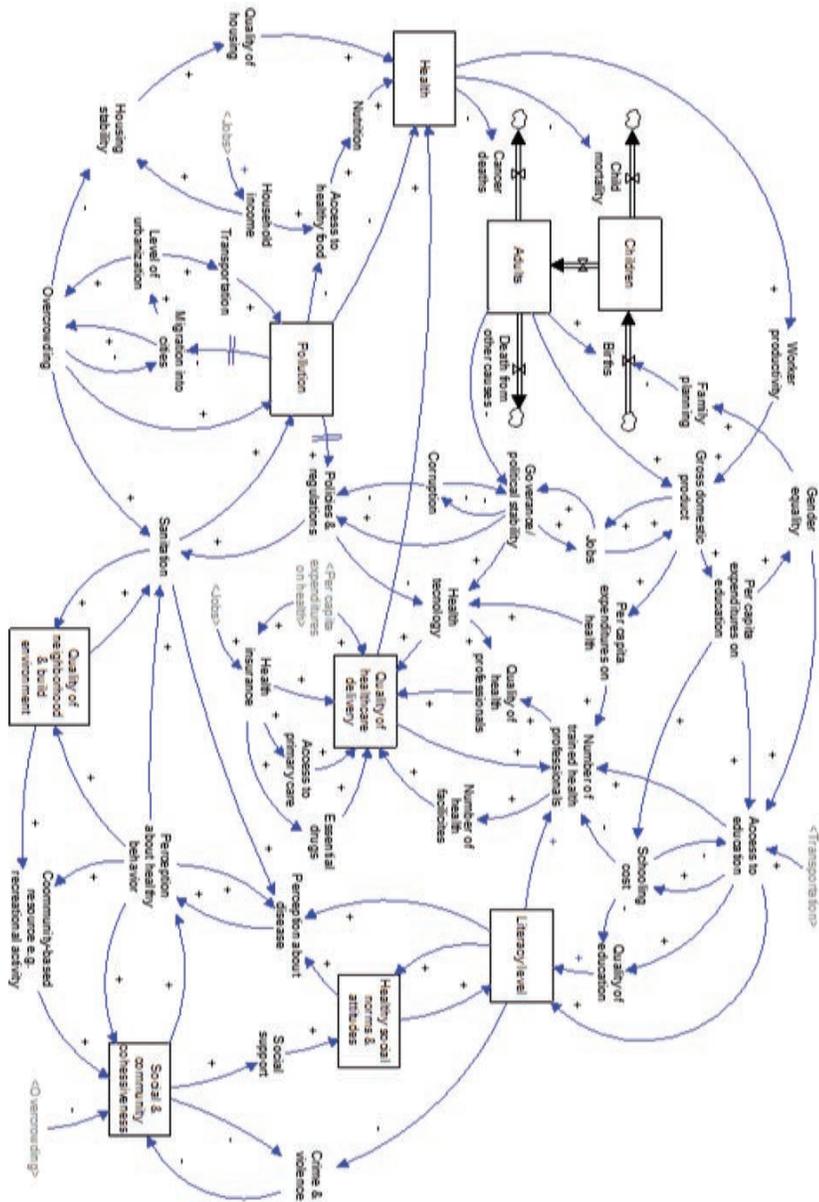


Figure 9.4: Causal framework of social determinants of health and global cancer disparities

global health inequalities in healthcare and cancer care. The rising rates in cancer in developing countries have been attributed in part to lifestyles similar to the developed countries [4-6]. The model shows how the built environment can have profound effects on the health of the population. Access to transportation will ease travel time and access to health care. Also, low crime rates for instance will encourage people to lead more active lifestyles. However, lack of community resources, high pollution and crime rates are likely to influence physical inactivity and exacerbates diseases like cancer.

### 9.3.2 A System Dynamics Framework and Feedback Structure for Global Cancer Disparities

Based on the review, we synthesized the results in the form of a system dynamics causal map, specifically a hybrid diagram that uses both the stock and flow conventions of system dynamics and a causal loop diagram (see Figure 9.4). Figure 9.4 has 8 major accumulations or stock variables shown in boxes as: children and adult population, overall population health (health), pollution, quality of healthcare delivery, quality of neighborhood and built environment, social and community cohesiveness, healthy and social norms and attitudes, and literacy level which shows a high level diagram capturing the major feedbacks in the system. The population is represented as a stock and flow structure where the boxes represent the current stocks of the main system and the double lines (“pipes”) with two triangles (“valves”) represent the flows or rates of change to the stocks [11]. For example, the stock of children increases with births and decreases with child mortality and children aging into adulthood. The rest of the diagram (Figure 9.4) is a causal loop diagram where the other key stocks are also drawn with boxes, but the flows represented the rates of change to the stocks are excluded to improve the readability of the diagram.

The 8 stocks are related through a set of hypothesized causal mechanisms (single lines with arrowheads showing the direction and polarity of the cause-effect relationship) identifying the potential role of multiple interacting feedback loops as explanations for trends in global health cancer disparities. The double lines crossing the causal links represent significant delays between causes and effects. The plus signs mean that increasing the cause variable increases or adds to the effect variable with everything else being held constant. In contrast, minus signs mean that increasing the cause variable decreases or subtracts from the effect variable with everything else held constant [38].

There are two major types feedback loops in a system: reinforcing and balancing loops. Reinforcing feedback loops amplify or accelerate the rate of change. For instance, the larger worker productivity, the greater the growth of GDP, which will lead to more availability of jobs, leading to higher household income for workers. Higher incomes then enable greater access to healthy food which improves nutrition, health, and “feeds back” to increasing worker productivity to form a reinforcing feedback loop (see Figure 9.4). Reinforcing feedback loops can generate “virtuous cycles” and “vicious cycles”. The feedback loop just described can work in the favorable direction, but the *same* feedback loop or structure can also operate in the unfavorable direction as a “vicious cycle”.

Balancing feedbacks counteract and oppose change. For example, migration into cities increases overcrowding which can contribute to pollution, which eventually slows migration into cities (see Figure 9.4). This balancing loop counteracts the

initial increase of migration.

## **9.4 Discussion**

### **9.4.1 Children, Adult and Overall Population Health**

One of the greatest public health achievements over the last two decades is the decline of childhood mortality in developing countries [10]. These improvements can be attributed to vaccinations against childhood infections, antibiotics against a wide range of bacterial infections, oral rehydration therapy for diarrhea, and in some places, generally improved living conditions [10]. Nonetheless, the growing burden of the cancer epidemic in low- and middle-income countries, due to increases in life expectancy and behavioral life style changes, means more will eventually die from the disease. An estimated 18% of cancer deaths in low- and middle-income countries can be attributed to smoking [12]. Overall, about one-third of cancers in low- and middle-income countries are preventable, considering risk factors such as tobacco use, unhealthy diet, alcohol consumption, sedentary behaviors, pollution and infectious agents [1,12].

The health of a nation's population is considered the fundamental importance to a country's well-being and ability to prosper economically. Protecting the health of the population contributes to society by enhancing an individual's current productivity, as well as that of future generations. If an individual's health is compromised, there will be serious negative consequences for families, communities and the entire process of economic and social development. Sadly, faced with competing health priorities, most low- and middle-income countries lack the resources to address the challenge of cancer [13]. While more than 80% of the global cancer burden occurs in less to middle-income countries, less than 5% of global health spending is on cancer [13]. This problem is compounded by varying degree of structural disparities inherent in stigmatization, poverty and lack of political will, resulting in lack of access to quality healthcare cancer control program [13,14]. Considering that the vast majority of the population in low- and middle-income countries cannot afford the cost of cancer treatment, a diagnosis of cancer does nothing but contributes to the vicious cycle of poverty.

In the causal map we highlighted the relationship between health and productivity and its effect on poor health, worker's productivity and earning power, as well as its contribution to a cycle of poverty, health and human capital outcomes across generations (see Figure 9.4). Lower productivity of workers can lead directly to poverty trap whereby reduced output of mothers and fathers due to poor health also leads to poverty and, subsequently, to a worsening of health outcomes for their children. For example, adverse health events may result in child labor substituting for the work of their parents, potentially lowering children's educational attainment and their own future productivity. Parental illness or death will not only limit productivity in the labor market, but also impact the ability of parents to care for their children; greatly increasing the risk that adverse health events will have long-lasting consequences [15]. The expectations for a short life span will also reduce savings, and thus investment in physical capital. Secondly, disease and early mortality among the children themselves have adverse inter-temporal effects. Illness and malnutrition among children reduce the incentives for parents to invest in their education. This is manifested in both delayed entry into school, as well as early exits. Disease and

hunger also diminish cognitive functioning and the ability to learn, thus diminishing the quality of health and literate population (see Figure 9.4).

### 9.4.2 Pollution

For many years, air pollution was considered a major problem of environmental health. Several studies have reported an association between atmospheric pollution and diseases such as cardiovascular, respiratory in terms of high mortality and morbidity [16,17,39-47]. A study by Cohen et al. [17] on the global burden of disease due to outdoor air pollution found that outdoor particulate matter (PM) air pollution is estimated to be responsible for about 3% of adult cardiopulmonary disease mortality; about 5% of trachea, bronchus, and lung cancer mortality; and about 1% of mortality in children from acute respiratory infection in urban areas worldwide. This amounts to about 0.80 million (1.2%) premature deaths and 6.4 million (0.5%) lost life years. In the United States studies [18,19] have also reported a link between air pollution cancer risks among urban residents. Similarly, in Europe Barbone et al. [20] also indicated an increased risk for lung cancer among city residents living in the most polluted areas than those living in less polluted neighborhood. In spite of these findings, the debate surrounding the effect of environmental air pollution remained unresolved until recently when air pollution was officially classified as carcinogenic to humans by WHO experts [2]. The International Agency for Research on Cancer (IARC) concluded that there is sufficient evidence that exposure to outdoor air pollution causes lung cancer, and an increased risk of bladder cancer. “The air we breathe has become polluted with a mixture of cancer-causing substances,” says Dr. Kurt Straif, Head of the IARC Monographs Section [2]. While the levels of pollution vary between/within countries as well as urban and rural areas, its effect is expected to be greater in less developed countries especially Africa and Asia due to massive undergoing economic development resulting in rapid levels of urbanization air pollution [48, 49].

Even though increased economic growth and development is associated with increased urbanization, the majority of urban population growth in less developed countries occurs among people living in poverty and results in growth of slums, overcrowding and unsanitary conditions. In the model, we argued that pollution negatively affects the overall health of pollution that will result in reduced worker productivity, gross domestic product (GDP), per capita expenditure on health, access to education, quality education and general literacy level (see Figure 4). Available evidence suggests that economically deprived communities have higher risk for related air pollution morbidity and mortality due lack of access to healthcare services, poorer nutrition and other factors [48,49]. Air pollution could therefore exacerbate the deplorable health conditions of in poor regions of the world. In addition, Gouveia et al. [21] and Jerrett et al. [22] have all argued that low level of education and income are associated with increased related air pollution health effects. These findings have therefore underscored the importance of social determinants to global cancer disparities.

According to the United Nations Population Fund (UNFPA), about half of the world’s population currently lives in towns and cities. However, by 2030 this number is expected to increase to 5 billion people with Africa and Asia experiencing most of these transformations [51]. While urbanization has the potential to lead to economic development, it can also lead to rise in slums, poverty, disparities and unhealthy life

styles. In the model we argued that migration to the cities will increase the level of urbanization which in turn will lead to overcrowding and its health hazards (see Figure 9.4).

### 9.4.3 Quality of Healthcare Delivery

While global concern about health inequities is growing, very little attention has been focused on the rapidly increasing toll of cancer in developing countries. As noted by the International Union against Cancer 2010 (UICC), the odds of surviving cancer based on the type of treatment one receives, including basic palliative care are strongly correlated with place of residence [23]. Whereas in the United States the five-year survival rate for patients with breast cancer is 84%, in the Gambia, it is only 12% [24].

Further, advances in biomedical technology, resulting in new improved cancer management have contributed to a considerable decrease in cancer mortality rates in most developed countries [25]. Cancer, once considered a disease of affluence, has become a death sentence in the developing world due to the absence of healthcare services and cancer drugs. According to the Institute of Medicine, cancers in low-middle income countries are diagnosed much later. It is estimated that up to 80% of cancers are detected at late stage hence, incurable by the time they are discovered [10]. Limited access to health services, poverty, lack of insurance, primary care, unhygienic practices are major factors contributing to the widening disparity gap between advanced and less developed nations.

It is a fact that every country has its own specific cancer burden features, risk factors, culture, health system, and available financial and human resources. Consequently, the level and degree of disparity also differ within and between countries. In the developed Organization for Economic Cooperation for Development (OECD) countries access to healthcare services is universal, but inequalities in health status have been shown to be related to income and other socio-economic factors [26,27]. In the model, we indicated that social determinants of health delivery is influenced by the effects of other social factors like per capita expenditures on health, jobs opportunity, health insurance, access to primary number of trained health professionals, number of health facilities, quality of health professions, health technology among others (see Figure 9.4).

The model on Figure 9.4 further highlights some of the major feedback structure that show the relationship between quality of healthcare delivery and general health and well-being as well as the ultimate impact on global cancer disparities.

### 9.4.4 Quality of Neighborhood and Built Environment

The neighborhood where we live and its environs can influence our health, depending on the factors such as the community design, recreational activity, quality of housing, schools, access to medical care and food, transportation, and air and water pollution [28,53]. Owen, Obregon and Jacobsen [29], analyzed the impact of geographic access to health services in rural Guatemala and indicated that the poorest communities in Alta Verapaz have the least geographic access to health center. Another study conducted by Campbell and colleagues [30] in Scotland on rural factors and cancer survival revealed that increasing distance from a cancer center was associated with greater chance of the patient being recorded as a death certificate only (*DCO*

– patients for whom only the death certificate provides notification to the cancer registry) case for stomach, breast and colorectal cancers. In Taiwan, Chang et al. [31] suggested that the existence of inequality in healthcare resources like available diagnostic tools and treatment technologies in rural areas are contributing to higher risk of nasopharyngeal cancer in rural areas. While regional and district hospitals have CT scans to help staging rural hospitals do not have these services and where they are available, they may be too expensive for patients to afford it. Health is also shaped by social relationships. For instance neighborhood where residents express mutual trust have been reported to have a lower crime and homicides rates [32].

According to Maller et al. [33] health cannot be separated from other social determinants. The interplay between people and their environment constitutes the basis for a socio-ecological approach to health and well-being [33]. Using the casual mechanism the model explained how neighborhood and built environment contribute to cancer disparities. For instance, friendly and safe environment would encourage residents to engage in physical activity. Through regular physical activities, neighbors become more engaged leading to more social and community cohesiveness and support. Interaction with family, friends, neighbors and co-workers would increase a sense of identity and eliminating stigma and unhealthy norms and attitudes about cancer and finally improved understanding about healthy life styles (see Figure 9.4).

### 9.4.5 Social Norms and Community Cohesiveness

Social norms are sets of rules that define appropriate and inappropriate values, behaviors, beliefs and attitudes within a group. Norms are created for several reasons: (1) to maintain cohesive order in a group or society as a whole, (2) to define boundaries of appropriateness and (3) to create a collective sense of community [34]. Social norms and cohesiveness also provide a model for understanding human behavior that has important implications for health and well-being.

To eliminate health disparities, it is important to understand the influence of culture on each society's beliefs, attitudes and public health practices [35]. For example, gender and cultural norms and values, in some society may give rise to gender inequalities. In some cultures a woman cannot receive needed healthcare from a male because norms in her community may perceive that as a taboo. Lack of cohesion is also associated with higher levels of crime, fear of crime and antisocial behavior. In our model framework, we indicated that a higher level of social cohesion may also provide more social support and mutual respect, and influence beliefs, practices and perceptions about cancer and other related health (see Figure 5).

Similarly, healthy social norms and community cohesiveness can facilitate support to promote higher literacy level in the community, which can also enhanced people's perception about cancer and other diseases, as well as their perception to engage in healthy behavioral life styles changes like participating in recreational activities leading to more healthy norms in the community (see Figure 9.4).

### 9.4.6 Literacy Level

Formal education is not an end to health literacy, but an important element for economic development. However, the fact remains that illiteracy is still high and costing the world lots of money [36,37]. According to the World Literacy Foundation, illiteracy costs the global economy almost USD \$1.5 trillion dollars each year

[37]. Although the severity of illiteracy varies between developed and less developed countries, its effects are similar, including inability to have employment and low income earning jobs and potentially remaining in poverty. Education can lead to improved health outcomes, in that more educated individuals make better informed health decisions [32,36]. For example, a low literate society is characterized by high level of crime and violence, low social and community cohesiveness which will intend leads to low social support and unhealthy social norms and attitudes. The causal map framework in figure highlights the importance of literacy, healthy social norms and social norms and community cohesiveness and their contribution to global cancer disparities. For instance, higher level of literacy will lead to improved personal hygiene practices and healthy life styles and perceptions about diseases and removal of stigma on those who suffered from it (see Figure 9.4).

## 9.5 Conclusions

Addressing these determinants of health requires effective dynamic approaches to improving global cancer health. Using causal loop diagramming, we provided a synthesis of the research from a system dynamics perspective by identifying underlying factors of global cancer disparities, how they are interrelated in the system and the consequences on health and well-being. Despite the challenges of eliminating health disparities, we believe the application of a systems thinking methodological approach is necessary to provide new understanding on how global development trends combined with global health efforts to improve population health could shift cancer disparities and burden associated with the disease. This is necessary because public health challenges are particularly complex, because they are often intertwined with much larger organizational, social, environmental, and cultural problems. Understanding these issues is essential to enhance the design and implementation of programs and policies to meet the needs of each specific environment. Subsequently, it is essential to approach global health issues from a broad systems perspective in order to have a comprehensive understanding of how factors are interconnected and interacting within the whole system. For future work we propose focusing on developing a quantified computer simulation model to identify and assess potential leverage points for intervention.

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# CHAPTER 10

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## Transdisciplinary Approaches in the Development of Novel Therapies for the Treatment of Fibrotic Diseases

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Fibrotic disorders represent a major health problem in the United States, contributing to nearly 45% of deaths each year. Further, the incidence of fibrotic disease continues to rise. Despite numerous drug candidates that have advanced to clinical trials, there have been numerous clinical trial failures and treatment options for fibrotic disorders remain limited. It has become critical to re-evaluate the current paradigm by which treatment options have been developed. Although fibrotic disease predominately affects the elderly population, age-associated pathological mechanisms have not been targeted in the development of treatments for fibrotic disease. *Nox4* is a well-validated target for fibrotic disease, and aberrant regulation of *Nox4* in aging is associated with pathological fibrosis. Through transdisciplinary approaches, we have identified the first selective and effective small-molecule inhibitors targeting *Nox4*, which are currently in pre-clinical development as a novel therapeutic for age-associated pathological fibrosis.

**Keywords:** Fibrosis, drug discovery, *Nox4*.

### 10.1 Introduction

Fibrosis is the clinical term for scar tissue. Fibrosis or “scarring” of vital internal organs is an increasing cause of debilitation and death worldwide. Human fibrotic disorders affect many organ systems including the liver [1-3], skin [4], kidney [5, 6], heart [7, 8], and lung [9-11]. An estimated 45% of deaths in the U.S. are attributed to disorders that are characterized by varying degrees of fibrosis [12]. This alarming statistic is often underappreciated since the ‘cause of death’ is often end-stage organ failure; however, organ failure is often attributed to progressive fibrosis. Further, the incidence of fibrotic disease is increased with advancing age, accounting for a growing “epidemic” of fibrotic disorders in the aging U.S. population. However, there are no available therapies which can ‘reverse’ fibrosis. Despite efforts by numerous groups

to develop treatments for fibrotic disorders, progress has been aggravatingly slow. This chapter will discuss some possible explanations for this apparent discrepancy and how transdisciplinary approaches to drug discovery and pre-clinical development may improve successful translation of more effective therapies.

## **10.2 Aging, Oxidative Stress, and Fibrosis**

Fibrotic disorders represent a major health problem in the U.S. An estimated 45% of deaths in the U.S. are attributed to disorders that are characterized by varying degrees of fibrosis [12], with a rising incidence. This may be in part due to the growing elderly population; progressive fibrosis is a hallmark of aging in various organ systems, including the liver [13], kidney [14], pancreas [15] and lung [16].

The most severe fibrotic lung disease is idiopathic pulmonary fibrosis (IPF), a fatal and relentlessly progressive disorder. IPF affects approximately 200,000 people in the U.S. and five million worldwide. Although two drugs have recently gained FDA-approval for IPF, no drug treatment has been shown to definitively improve quality of life for IPF patients and they have only been shown to delay death by 6 months. The current drugs only moderately slow the progression of lung decline. There are no available therapies which can 'reverse' fibrosis. Further, these therapies (both orally administered) are associated with a number of significant and intolerable side-effects. Effective treatments for IPF and other fibrotic diseases are needed in order to improve the patient experience and outcomes.

Aging is a major risk factor for fibrotic disorders. This point is exemplified by IPF, which disproportionately affect the elderly population [17, 18]. IPF is now widely regarded as an age-related disease [19-21]. The incidence and prevalence of IPF increase with age; two-thirds of IPF patients are older than 60 years at the time of presentation with a mean age of 66 years at the time of diagnosis [17]. Further, the survival rate for IPF patients markedly decreases with age [19]. A better understanding of the contribution of aging to the cellular/molecular mechanism(s) involved in the pathogenesis of IPF is sorely needed.

Aging and fibrotic disease are both associated with cumulative oxidant burden, and lung tissue from IPF patients demonstrate "signatures" of chronic oxidative damage [22, 23]. It has been suggested that core pathways that mediate fibrosis in multiple organ systems may serve as better targets for anti-fibrotic drug development [24]; redox imbalance in the context of aging has been suggested to represent one of these core pathways [25]. Despite the well-recognized role of oxidative stress in aging and fibrosis [26], the ability to precisely target key mediators of this process have not been identified or developed. Anti-oxidant strategies have failed in clinical trials [27]. Strategies which directly target the source(s) of reactive oxygen species (ROS) generation are more likely to be more specific and effective in comparison to antioxidant interventions.

## **10.3 Development of Age-relevant Animal Models for Pre-clinical Testing**

One major limitation in the pulmonary fibrosis scientific field is the lack of animal models that reliably predict therapeutic efficacy of agents in clinical trials [28,

29]. The most widely used murine model utilizes bleomycin to induce lung fibrosis. However, despite promising pre-clinical efficacy of numerous therapeutic agents using this animal model (>240 experimental drugs evaluated), clinical translation has been poor [28]. Thus, the use of this model for pre-clinical evaluation of drug candidates has been questioned. One potential reason for the lack of clinical translation is not the model per se, but the failure to account for the widely acknowledged concept that IPF is an age-related disease [19-21]. Pre-clinical animal models of lung fibrosis are largely employed in young rodents (8-12 weeks); in this model, injury-induced fibrosis is self-limited, with resolution of injury [30]. Thus, pre-clinical treatment interventions employed are largely preventative (dosing before or at the time of injury), rather than curative [28]. Although this model is a tremendously useful tool for identifying therapeutic targets involved in fibrotic responses to lung injury, its utility as a pre-clinical efficacy model has proven to be substandard.

Previous studies in our lab evaluated reparative responses to lung injury in young (2m) and aged (18m) mice. Mice were administered intra-tracheal bleomycin, and sacrificed at 0d (no injury), 3w, 2m, and 4m post-injury. Our studies revealed that severity of fibrosis at 3w post-injury (the peak fibrotic phase) was similar in both young and aged mice. However, young mice demonstrate significant resolution of fibrotic injury (~60% resolution at 4m post-injury), whereas aged mice exhibited an impaired capacity to resolve fibrosis (with little to no resolution of fibrosis at 4m post-injury) [10]. The resolving nature of bleomycin-induced lung injury in young mice supports reversibility of fibrosis – a property that is lost with aging.

An age-relevant model offers the following advantages over the current prevailing pre-clinical model:

1. Fibrosis that better mimics the persistent/progressive nature of fibrosis seen in IPF patients.
2. A more representative animal model for a disease that predominantly affects the elderly population.
3. The ability to implement more clinically relevant testing protocols (i.e. determine the effect of a drug candidate on reversibility of established/persistent fibrosis).
4. It permits long-term examination of physiological parameters (i.e. survival, body weight, lung compliance) which are more appropriate indicators of the potential for therapeutic success.

Overall, the use of this model in pre-clinical efficacy approaches is more likely to result in improved accuracy of predicting therapeutic potential in clinical trials, and may prevent time-consuming, costly, and ultimately unsuccessful clinical trials.

## **10.4 Novel Pro-fibrotic Mechanisms in Age-associated Pathological Fibrosis**

The pathogenesis of IPF remains poorly understood. “Fibro-proliferation” has been implicated as a key mechanism for the persistence (vs. initiation) of fibrosis; however this is inconsistent with the clinical observation of an increased risk of fibrotic disease with advancing age. Recent studies from our group (using the aged mouse model described above) offer new insight into how aging leads to a predisposition to fibrosis.

Our group was the first to identify a novel role for the oxidant generating enzyme, NADPH oxidase-4 (Nox4), in mediating lung fibrosis (2009); since then, Nox4 has also been implicated in a variety of fibrotic diseases, including the liver, skin, kidney, and heart. In resolving fibrosis in young mice, lung myofibroblasts (the key ‘scar tissue generating’ cells) eventually undergo apoptosis (programed cell death) to promote healing. In contrast, in aged mice with non-resolving fibrosis, myofibroblasts acquire a senescent and apoptosis-resistant phenotype, which contributes to myofibroblast accumulation and ultimately persistent fibrosis. Specifically, age-dependent alterations in Nox4 results in a sustained redox imbalance, which promotes senescence and apoptosis-resistance of myofibroblasts [10]. Thus, the ultimate fate of these normally reparative cells is altered in the context of aging, where they acquire an apoptosis-resistant phenotype that contributes to the persistence of fibrosis (whereas apoptosis of these cells is a hallmark of fibrosis resolution). In support of this concept, we have also demonstrated that human IPF lung myofibroblasts are predominantly non-proliferative and

demonstrate features of senescence and apoptosis-resistance [10]. Importantly, we demonstrated that Nox4 mediates senescence and apoptosis in vitro, and that therapeutic targeting of Nox4 in an aging model of persistent fibrosis resulted in decreased senescence and susceptibility to apoptosis in vivo [10]. This previously unknown profibrotic mechanism may help to explain why IPF develops more frequently in older individuals. However, therapeutic targeting of age-associated pathologic mechanisms in the development of IPF treatments remains unexploited.

## **10.5 Selective Nox4 inhibitors have not been previously identified**

Although Nox4 is considered to be among the most promising targets for fibrotic disease, no selective Nox4 inhibitors are clinically available. Nox4 drug development has proved challenging for several reasons. The crystal structure of Nox4 is not known, which precludes traditional rational drug design approaches. Further, screening methods for Nox inhibitors typically utilize ROS detection-based screening assays that have limited specificity. Thus, it may be difficult to discern whether a putative inhibitor is acting directly on Nox versus inhibition of a signaling pathway(s). One study reported that of >350 ‘Nox inhibitors’ described, a majority of these did not directly block Nox enzymatic activity, but rather they showed interference with upstream signaling pathways or demonstrated ROS scavenger activity [31]. Genkyotex (Geneva, Switzerland) is developing a candidate Nox1/4 inhibitor (GKT137831) for diabetic nephropathy. However, selectivity of GKT137831 for Nox4 is low relative to other Nox isoforms; it has been reported to inhibit Nox4 (82%), Nox1 (86%), and Nox2 (60%) [32]. There are industry concerns regarding the specificity of this compound for drug development aimed at fibrotic disorders; particularly since Nox2 plays well-described roles in inflammation, and anti-inflammatory strategies have been shown to lead to worse outcomes for IPF patients [33]. Identification of small-molecule inhibitors that selectively target Nox4 has been a major challenge.

## 10.6 Transdisciplinary Approaches to Drug Discovery and Pre-clinical Development

Despite efforts by numerous groups to develop IPF treatments, progress has been aggravatingly slow. We offer two possible explanations for this discrepancy:

1. Although IPF is widely regarded as an age-related disease, drug treatments have not targeted age-associated pathologic mechanisms of IPF, and
2. current pre-clinical animal models fail to reliably predict the success of drug candidates in human clinical trials. We believe that transdisciplinary approaches to drug discovery and pre-clinical development are critical to the development of effective therapies for IPF (i.e. age-relevant animal models and therapeutic targeting of age-associated pathological mechanisms).

Given the accumulating data on Nox4 as a “core pathway” in diverse fibrotic disorders, the search for safe, specific and effective Nox4 inhibitors continues. An overall goal of our laboratory is to identify a lead drug candidate that is highly selective and effective in inhibiting Nox4, with favorable pharmacokinetic/pharmacodynamic properties for subsequent clinical development as a therapy for IPF. We have screened over 30,000 compounds and through our medicinal chemistry and hit-expansion efforts, we have identified 2 novel classes of small-molecule inhibitors that are highly effective and selective in inhibiting Nox4. Our biophysical characterization studies demonstrate favorable qualities of our leads for subsequent clinical development. Two U.S. patent applications have been filed. Pre-clinical development of these novel inhibitors remains ongoing in our laboratory. Current and future success of our mission is highly dependent on the transdisciplinary nature of our team, including researchers, physicians, collaborators, consultants, and an advisory board with specialized expertise in key areas (intellectual property, commercialization, successful clinical translation, and patient advocacy).

## 10.7 Conclusion

It has been suggested that core pathways that mediate fibrosis in multiple organ systems may serve as better targets for anti-fibrotic drug development [24]; Redox imbalance in the context of aging has recently been highlighted as one of these core pathways [25]. However, despite the well-recognized role of oxidative stress in fibrosis and aging, the ability to precisely target key mediators of this process has proved difficult. Nox4 represents a well-validated therapeutic target for fibrotic disease. Further, recent studies support an age-associated defect in Nox4 regulation, thus targeting of Nox4 represents a plausible strategy for age-associated pathological fibrosis. However, despite the identification of this well-validated target, the successful clinical translation of treatments for fibrotic disease will require transdisciplinary approaches to drug discovery and pre-clinical development.

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## About the Author



**Dr. Hecker's** broad research background and training has been rooted in regenerative biology, with experience in development, tissue engineering, and mechanisms of injury-repair. Her research team previously identified a novel role for NADPH oxidase-4 (Nox4), an oxidant-generating enzyme, in mediating myofibroblast functions and scar tissue formation (fibrosis), published in *Nature Medicine*. Since this discovery, her research interests have expanded to include understanding the role of aging/senescence in lung injury-repair responses. Dr. Hecker's current research interests also encompass translational aspects, including drug discovery for Nox4 and the development of preclinical animal models of acute lung injury and fibrosis.

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# CHAPTER 11

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## A Hyperspectral Signature Method for Identifying E. coli: Impact on Public Health

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Using a non Shiga toxin producing Escherichia coli such as the lab K12 strain we will demonstrate a method to develop signatures suitable for hyperspectral data searches. Conventional laboratory methods remain the mainstay to isolate and identify suspected sessile and platonic bio-material, however the FDA Food Safety Modernization Act (FSMA), Jan 04, 2011, is requiring additional proactive identification and monitoring. These proposed methods could allow higher screening coverage without additional laboratory time. These standard test are laborious and can take days to complete. Optical, noninvasive techniques such as hyperspectral remote sensing technology has been adapted for microscopic sensing. Many applications have pursued this avenue with varying degrees of success. As the cost of hyperspectral detectors falls, the promise of an optical detection solution is within reach. The goal of this research is to develop a detection method based on hundreds of cells still in their platonic stage before the damaging effects of their more colonized form develops. Once colonized, removal is much more difficult as environmental coping mechanisms are fully developed. The objective is to determine a HSI signature that has a low false alarm rate ( $F_a$ ) from unstained (low contrast) and stained (high contrast) samples.

**Keywords:** Hyperspectral, ISODATA, spectral angle mapper, spectral correlation mapper, hypercube, HSI signature

## 11.1 Introduction

As the food chain grows to a global distribution system, different levels of consumer concerns must be addressed. One of these concerns that directly affects our health, especially those who may be immune compromised, pregnant, very young or old, is common microbiological contaminations such as *E. coli*. For consumers, the detection of such is nearly impossible and we rely solely on appearance of the product and description on the package [1] and reputation of the vendor.

*Escherichia coli*, usually called *E. coli*, is a type of bacteria that lives in the intestines of humans and animals. Although most types of *E. coli* are harmless, some types such as *E. coli* O157: H7, can make people sick, causing serious stomach cramps, diarrhea and vomiting. Serious complications of an *E. coli* O157:H7 infection can cause permanent organ damage such as kidney function loss or death.

People get *E. coli* infections by eating foods containing the bacteria. Symptoms of infection include: Nausea or vomiting, abdominal cramping, sudden, severe diarrhea that may cause bloody stools, pallor, high blood pressure, gas, fatigue, and fever. *E. coli* infection may initiate devastating illness such as Hemolytic Uremic Syndrome (HUS), particularly in children young and mature adults which can cause life-threatening complications.

Tens of thousands of kilos of fresh fruit and vegetables in the country are being destroyed as consumers across Europe and beyond shun these staples for fear of contracting the potentially deadly bacteria [2]. *E. coli* contaminations are both common as cross contaminations are both easily fostered and prevented however difficult to detect.

The increased public awareness has demanded greater controls and advancement in food quality controls. As Rahman [3] stated, food products that are preserved depend on a multitude of hurdles being properly controlled. One of which is the microbial population in the product. Critical limits, known as the hurdle effect, are controlled with heat, temperature and chemical treatments however quantifying the microbial content is a slow process that requires professional laboratory implementations. Much work has been done in defining these hurdles [4] and their interactive causal effects. Leistner defined F values to quantify variables such as acidity (pH and titratable), moisture content and correlate to microbial colony populations in relation to these values. The use of hyperspectral technology to successfully quantify the food safety variable space is supported by many research programs such as Zhu [5], as he demonstrates the ability to determine the frozen history of products using visual infrared and near infrared (VIR/NIR) screening.

The signature is without doubt the value added commodity within the area of research concerning hyperspectral data mining. Because of their intrinsic value and system specific nature most systems will not depend upon reuse and will develop their own set of signatures. In none of the literature, did we find formal standards nor even the suggestion of a standard that would allow a greater degree of portability. A signature is a mathematical device used to mine hyperspectral imaging (HSI) data in an effort to determine the material composition of a given scene. A spectral peak followed by decay then followed by a combination of the same, e.g., will typically constitute a mathematical signature. The mathematical relationships vary widely, using various geometric measurements, distance from DC, and relative positions to patterns detected by machine learning applications.

The signatures developed here are multi-component constructs that can indepen-

dently produce some degree of success during a field search. We used two different base line algorithms and then integrated them together taking advantage of their strengths to create a single algorithm that is stronger and produces a lower  $F_a$ . The primary component in our algorithm is the Spectral Angle Mapper (SAM) [6, 7, 8, 9] which characterizes the shape of a line when compared with a baseline standard. The second component that is integrated into the ID chain is known as a Spectral Correlation Mapper (SCM) [10, 11] which measures the strength of the linear relationship between two variables.

## 11.2 Microbiology Introduction

Most *E. coli* strains are harmless, but Shiga toxin-producing *Escherichia coli* (STEC) can cause food-borne disease in our cattle and beef products. STEC is one of the most important factors affecting the beef industry and is one of the public health threats faced in food processing. *E. coli* O157:H7 is the most commonly identified STEC in North America and has been illegal in beef products since 1994. *E. coli* O157:H7 and other serotypes cause approximately 113,000 illnesses and 300 hospitalizations annually, according to the Centers for Disease Control and Prevention (CDC). Identification and removal of contaminated beef products is therefore a critical concern for the cattle industry, and even contact with contaminated fecal matter (as fertilizer) can lead to spread of the pathogen in produce shipped to the marketplace. A direct screening method that can be employed in all areas of food screening and processing would therefore be useful as a deterrent to future STEC outbreaks. Methods in current use for STEC diagnosis include pulsed-field gel electrophoresis (PFGE) subtyping, and a conventional microbiological method involving cell counting. While these methods are accurate and remain as the gold standard for food-borne pathogen detection time is needed, from days to weeks to provide an accurate result. Therefore, a more rapid method of pathogen detection is needed that is very sensitive and accurate for classification of contaminated foodstuffs. Optical, noninvasive techniques such as hyperspectral remote sensing technology, adapted for microscopic procedures, may provide a needed venue for safe, fast, and efficient screening of possible contaminants. New applications of this technology as well as reduced cost make hyperspectral sensing a perfect candidate for identification of STEC in the food supply.

Bacteria colonizing the gut of an animal are typically found in multi-species biofilms lining the intestinal epithelium, and as such are also attached to a surface of some kind. A biofilm is typified as an aggregate bacterial community enclosed by extra-polymeric substance (EPS). Free-floating planktonic bacteria are released by the biofilm in regular intervals, to find new areas to colonize, and many of these will also attach to new surfaces readily in the gut and pass along attached to the fecal matter as well. The ability of these bacteria to attach to surfaces provides us with new opportunities to find hyperspectral signatures specific for the combination of the contaminating bacteria attached to the surface of the bound organic material. This ability to provide a hyperspectral signature against various backgrounds could lead to diagnostic tools that are far more specific and efficient in identifying STEC, as well as reducing lab workload.

Identification of bacteria bound to a surface also provides an advantage in that the bacteria are immobilized, reducing the effect of Brownian motion and “wiggling”

observed in the capture of hyperspectral images by Cray et al. [11] used with glass slides and traditional microscopy techniques. Agar plates with affixed *E. coli* colonies were used to generate our hyperspectral image (HSI) data. Our technique delineated in this chapter uses a data analysis protocol to sort through the accumulated HSIs to sort between real and trash data, producing a composite signature which can be used to verify the presence of *E. coli* bacteria. It is definitely possible that this signature can be developed against other bound bacterial-contaminated surfaces as well, leading to a library of potential signatures that can identify various contaminants in our food supply.

## 11.3 Materials and Methods

### 11.3.1 Data Set

A hyperpixel<sup>1</sup> is a three dimensional data construct that represents reflectance values at the step interval ( 10 nm ). In Figure 11.1 each tick along the X axis represents 10nm starting at 450 nm. Values have been omitted for image cleanness and did not contribute to the clarity of the message. If we plot a hyperpixel we may get something that looks like Figure 11.2 where reflectance  $R_x(\lambda_n)$  is plotted along the Y axis and wavelength ( $\lambda$ ) along the X axis. This image depicts the spectral spread as a continuous line however the hardware bins the spectrum into finite spectral ranges, grossly selectable by the user with a minimum step of 10nm (per end user sensor specifications). It's this binning that allows for the feature selection and pattern recognition sequences of unsupervised learning algorithms. This represents a single hyperpixel which correlates to a single XY location in a Cartesian image system. By organizing the hyperpixels into an image format addressed as in a XY system we create a three dimensional cube known as a hypercube addressable as [ X, Y,  $\lambda$  ], with  $\lambda$  increasing along the formal Z axis.

### 11.3.2 Target Environment

The target image is complicated because in the process of growing the specimen, the biologist has to provide fluid and nourishment for the bacteria to thrive. This is accomplished by adding a small colony into a rich agar material. The material is home grown by most commercial and academic labs. The Texas Tech Microbiology Department uses the following recipe: 5g yeast extract, 200 ul NaOH, 15g granulated agar mix, and 1L deionized H<sub>2</sub>O. This is but one of the series of variables that makes this HSI signature challenging. Of course there are the other compounds in the agar mix. We attempt to classify them as “media” in this study. Most of these detections are aggregated into single hyperpixels and can be isolated having a characteristic signature when they are the predominate end member in a pixel. Some however will have additional end members present within the projected pixel footprint resulting in what is known as a mixed pixel [12, 13, 14]. This mixing will confuse the signature resulting in a missed classification thus in this implementation will push it into known trash class or unclassified trash.

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<sup>1</sup>In traditional image processing, we refer to a pixel by its Cartesian address, where a hyperpixel is addressed the same, it carries additional spectral data per channel thus is modeled in three dimensions.

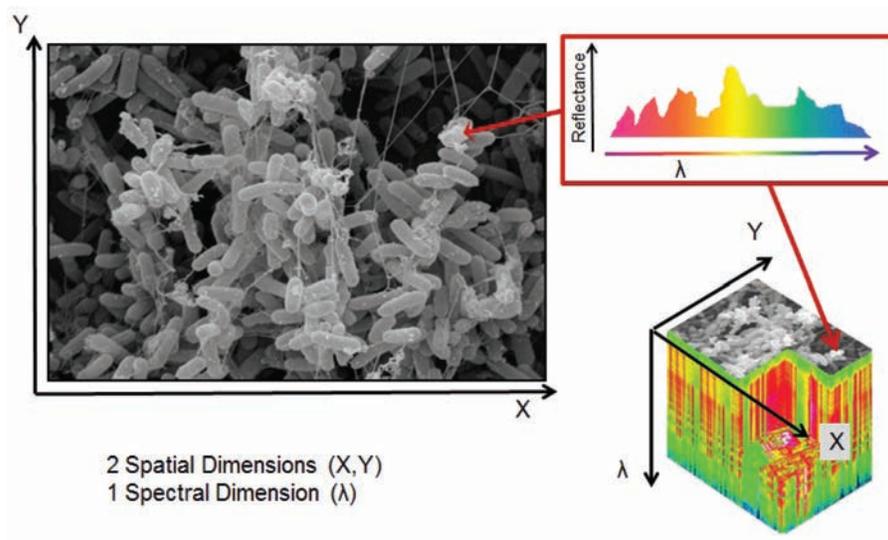


Figure 11.1: Three dimensional data construction.

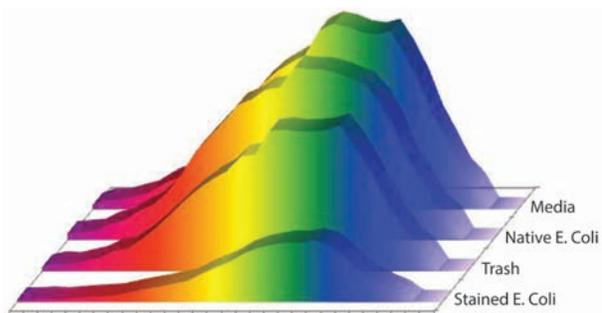


Figure 11.2: Spectral comparison of what we see under the microscope.

### 11.3.3 Developing Truth

Iterative Self-Organizing Data Analysis Technique A (ISODATA) is a method that performs unsupervised learning by formulating data into like clusters through a closest average fit with the fit factor ( $\omega$ ) being a user input. While not required, in our trials we have seeded the twelve bins (labeled A..L, with M being a catch all) with known data values (classifications), see Table 11.1. Through visualization these datum were selected and coded into the analysis as manual truth.

Initialization of the ISODATA algorithm, according to these authors [15, 16], each bin is to be randomly seeded. However, experience has shown that the runtime of the algorithm can be reduced by selectively seeding the bins thus providing guiding

**Table 11.1:** Enumerations identifying media types where targets are located.

Enumerator	HEX Value	Count
LIGHT_MEDIA	0x0001	14
LIGHT_STAINED	0x0002	18
LIGHT_UNSTAINED	0x0004	8
LIGHT_TRASH	0x0008	10
MED_MEDIA	0x0010	31
MED_STAINED	0x0020	22
MED_UNSTAINED	0x0040	13
MED_TRASH	0x0080	14
DARK_MEDIA	0x0100	49
DARK_STAINED	0x0200	45
DARK_UNSTAINED	0x0400	32
DARK_TRASH	0x0800	23

weight to its convergence for both algorithms. Unlike the ISODATA routine, this implementation does not allow the seeds to be reorganized thus providing a reloadable signature basis.

Several locations within the data have been selected and identified by a subject matter expert, in this case a doctoral candidate in microbiology, with extensive microscope experience. Enumerated values were assigned to the manually classified data points and counted. We noted the quality of the typical microscope light source was inconsistent with the constraints necessary to evaluate HSI data and broke the classifications into three general light levels, light, medium, and dark – a general reference to the collective reflectance quality of the tested image. Any unidentified artifacts are classified as trash knowing that future classification efforts may well identify them. The hex (base 16) values are randomly assigned and have value only in binning the data.

Confusion tables are commonly used in determining the correctness of the algorithm detections. In this case, Table 11.2, illustrates the ideal detections that would match the priori classifications. We then compare results with Table 11.2 as the algorithm is developed with the goal of greater than 97% accuracy.

## 11.4 Spectral Angle Mapping

The Spectral Angle Mapper classification (SAM) [17] is an automated method for directly comparing image spectra to a known spectrum (usually determined in a lab or in the field with a spectrometer) or an end member. This method treats both (the questioned and known) spectra as vectors and calculates the spectral angle,  $\omega$ , between them. This method is insensitive to illumination since the SAM algorithm uses only the vector direction and not the vector length. The result of the SAM classification is an image showing the best match at each pixel. This method is typically used as a first cut for determining areas of homogeneous regions.

The goal is to find waveforms that are similar to one another such that a signature could be determined and used in a search on non-training data. In this case training data is defined as data that has some known values however unknown to the selection

**Table 11.2:** Manually selected truth confusion table, values are hyperpixel counts.

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
Light Media (A)	14	0	0	0	0	0	0	0	0	0	0	0	0
Light Stained (B)	0	17	0	0	0	0	0	0	0	0	0	0	0
Light Unstained (C)	0	0	8	0	0	0	0	0	0	0	0	0	0
Light Trash (D)	0	0	0	10	0	0	0	0	0	0	0	0	0
Medium Media (E)	0	0	0	0	31	0	0	0	0	0	0	0	0
Medium Stained (F)	0	0	0	0	0	22	0	0	0	0	0	0	0
Medium Unstained (G)	0	0	0	0	0	0	13	0	0	0	0	0	0
Medium Trash (H)	0	0	0	0	0	0	0	14	0	0	0	0	0
Dark Media (I)	0	0	0	0	0	0	0	0	49	0	0	0	0
Dark Stained (J)	0	0	0	0	0	0	0	0	0	45	0	0	0
Dark Unstained (K)	0	0	0	0	0	0	0	0	0	0	32	0	0
Dark Trash (L)	0	0	0	0	0	0	0	0	0	0	0	22	0
Unclassified (M)	0	0	0	0	0	0	0	0	0	0	0	0	0

process. The known values are used to evaluate performance and indicate when the signature process has completed the training process. Just as primary schools use a grading level to measure progress of a student, the ISODATA routine uses some data metric to describe what it is attempting to classify. The Spectral Angle (SA) is useful as it describes the closeness of one vector to another. In this case we have a reference vector from one of the principal components selected,  $\vec{r}$  reference vector, and  $\vec{t}$  target vector.

$R_t(\lambda_n)$  is the target spectra for which the spectral angle is to be calculated. This is the hyperpixel data that contains the intensities per band for which we are searching for a key to identify a subclass of material.  $R_r(\lambda_n)$  is the reference spectra, or one of the principal components that were selected priori. In all cases the first sample selected is specific in that it becomes  $R_r(\lambda_n)$ .

$$r = \sum_1^n R_r(\lambda_n)^2 \tag{11.1}$$

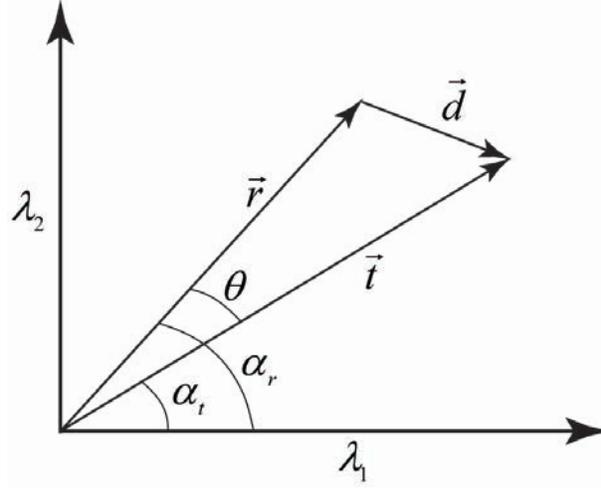
is the sum of the squares for the reference hyperpixel and

$$t = \sum_1^n R_t(\lambda_n)^2 \tag{11.2}$$

is the sum of the squares or the reference vector.

We plot these vectors in 3D space however for clarity and ease of referencing we demonstrate them in 2D space assuming the reader understands the inferred 3D plot. In finding Figure 11.3, we can see that  $\vec{r}$  and  $\vec{t}$  are plotted starting at the origin. It is note worthy here to explain that SAM is not interested in the magnitude of the reflectance value rather the angle between the two vectors. This makes SAM resilient to fluctuations in intensity due to poor lighting control.

We calculate the dot product



**Figure 11.3:** A simple  $\lambda$  on  $\lambda$  plot to explain SAM [10].

$$A \cdot B = \sum_1^n R_r(\lambda_{-n}) \times R_t(\lambda_{-n}) \quad (11.3)$$

which gives the spectral angle in radians as

$$\theta = \cos^{-1} \left( \frac{A \cdot B}{r \times t} \right) \quad (11.4)$$

Along with  $R_r(\lambda_n)$ ,  $\theta$  becomes the SAM reference value by which searches into the data set will attempt to identify *E. coli* and other classified endmembers. This approach allows for  $N$   $\lambda$  bins and attempts to minimize the fluctuation in lighting intensity. However SAM has limits as the resultant coefficient is a single value, and then allowing for some percentage of error, there exist the potential for the SAM to spill over into the ranges of dissimilar endmembers.

### 11.4.1 Spectral Correlation Mapping

We introduce a further refinement to the ISODATA method as the Spectral Correlation Mapper (SCM) algorithm, Eq. (7). SCM is generated in parallel, however is only conditionally evaluated when SAM is unable to discriminate or has multi-correlations.  $\bar{r}$  is the average of the iterative evaluations of 11.1 as is  $\bar{t}$  to 11.2.

$$\bar{r} = \frac{\sum_1^n R_r(\lambda_n)^2}{count} \quad (11.5)$$

is the mean sum of the squares for the reference hyperpixel and

$$\bar{t} = \frac{\sum_1^n R_t(\lambda_n)^2}{count} \quad (11.6)$$

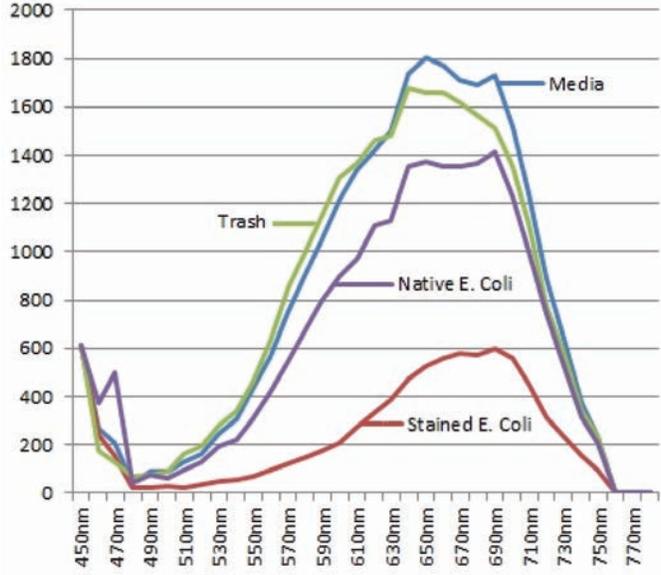


Figure 11.4: General aggregate signal shape of the four known classes.

Then the means are calculated where count is the number of samples in the signal. We now sum the products of the mean adjusted elements of both  $R_t(\lambda_n)$  and  $R_r(\lambda_n)$  arrays divided by the products sum of the mean adjusted squares of both  $R_t(\lambda_n)$  and  $R_r(\lambda_n)$ .

Where  $\alpha$  is formed as an angle (expressed in radians) describing the similarity between the reference hyperpixel spectrum (Y) and the hyperpixel under test (X). The SAM execution will generate results that are over classified or miss-classified. Given the shapes of the target signals, Figure 11.4, and the geometric similarity with the coexistent end members one can easily see how narrow the error budget is.

During the training process, the training data is evaluated via the SAM algorithm to produce pure spectral signatures. After an identified spectra has been identified it is then referred to as an *endmember*. We must assume, even at these path lengths the pixels will contain a variation of material signatures. Specifically we can reasonably expect to see our target bacteria and the expressed components of the emerging bio-film, agar materials, and expect random contaminations although efforts are put forth to minimize these. Thus the hyperpixels will contained a mixed signal and is subject to mixed pixel aberrations in the signal construct.

$$\alpha = \frac{(\sum_1^n R_t(\lambda_n) - \bar{t}) \times (\sum_1^n R_r(\lambda_n) - \bar{r})}{\sqrt{(\sum_1^n R_t(\lambda_n) \times \bar{t})^2 \times (\sum_1^n R_r(\lambda_n) \times \bar{r})^2}} \quad (11.7)$$

## 11.5 Implementation Details

The primary difference between the two methods is that the SAM is a single angular relationship along the horizontal axis; where SCM uses pairs of deviations, e.g.  $x - \bar{x}$  and  $y - \bar{y}$  to qualify the differences along both the horizontal and vertical axis. Combining the two methods yields a higher capacity to detect false positives.

As the training process progresses along the truth hyperpixels, it will average the resulting SAMs and SCMs yielding  $\bar{\theta}$  and  $\bar{\alpha}$  respectively. When the system runs as a detector, e.g. with known signatures, these averages will remain constant yielding the basis of the signature set, however in training mode the system is seeking the final values.

Refer to Figure 11.5 for the following algorithm flow description of the process. In both the learning and detection processing, we load the SAM and SCM coefficients by either calculating from the truth file or loading from a previously calculated learning run. Then entering a couple short loops, we exercise the  $\omega$  fit for both the SAM and SCM truth seeds. This narrows the user input  $\omega$  fit from typically 3 to 8 percent to a level that will independently resolve the truth set without overlaps or over fitting. This is shown in the flow chart as Do for SAM and Do for SCM loops.

Next we loop for class intersections between the SAM and SCM fits in order to narrow down to a selection. This processing state is valid for both training and detection. Given only one SAM fit and one SCM fit and they both agree, we log the selection in data and return the value to the caller function. The caller function will then advance the X,Y coordinate and begin the processing again. In the case of truth processing we will see the next logical hyperpixel in the truth list and in detection we will see the next logical hyperpixel as the X or Y value will have changed.

Assuming the next hyperpixel processing results in an intersection count  $>1$  then we look to narrow the overfit selection by determining which class has the closest fit where the SAM will converge to zero for a perfect match and SCM will converge onto one. In the flow chart  $\theta$  represents the SAM fit value while  $\alpha$  represents the SCM fit value and  $\omega$  is the tolerance around zero or one.

The differences are initialized assuming class 'A' holds the closest fit.  $diff$  and  $sdiff$  are initialized per Eqs. 8 and 9, respectively. The  $\Delta$  values are the differences between the now class average divergence from either zero or one and the hyperpixel under test divergence.

$$diff = \frac{\Delta\theta}{\bar{\theta}} \quad (11.8)$$

$$sdiff = \left| 1 - \frac{\Delta\alpha}{\bar{\alpha}} \right| \quad (11.9)$$

Then for each class B..L we logically compare the same results with the previous difference value selecting the one that is closest to either the SAM or SCM convergence value.

The SAM logic states if  $diff >$  the class evaluation of Eq. 8 then  $diff =$  the class evaluation else remains unchanged. Where the SCM logic follows suit but is looking for a difference in magnitude.

The final selection is done as if  $sdiff > diff$  then the selection class is the smaller  $\alpha$  otherwise its the smaller  $\theta$  class.



precedence as similar methods were explored by Fauvel [18]. This too mimics the findings of Jin's [9, 19] 80-20 rule where the SAM function identifies 80% of the targets and the SCM is optimized to pull in the remaining 20% with some error in identification accuracy. These two algorithms were independently developed in support of earth science programs and integrated here to solve the low noise low feature count found in a relatively flat fielded microscopic field of view.

Data was collected in November 2012 at the Texas Tech Health Sciences Center using the following environment. The Texas Tech University Health Sciences Center's Cell Physiology and Molecular Biophysics Imaging Center provided the following equipment in a dark room environment. The microscope is an Olympus TH4 - 100 and used 2 objective ends, 40X for dry measurements and a 60x for wet measurements. The wet imagery yielding the better imagery and is used for this research. The HSI sensor is a CRi Nuance FX HSI sensor system (Caliper Life Sciences, Hopkinton, MA, USA) connects to a laptop via USB connections. The room is light tight and adjacent to a common area for specimen preparation. The scientific-grade CCD imager ( 1392 x 1040 effective pixels ) features a solid state liquid crystal wavelength tuning element. The package is mounted onto a chassis with a standard C-mount camera tube. The CRi Nuance EX (450-900 nm) has a tunable liquid crystal element that provides vibration free control of wavelength selection. Vendor documented accuracy is Bandwidth/8.

The stock Olympus light source (non NIST) is used and the Nuance software is capable of flat fielding the illumination. Procedures outlined in the vendor documentation were followed. All samples are imaged in transmission mode [20] as most of the literature suggest for the most useful images.

Using Nuance<sup>TM</sup> (Caliper Life Sciences, Hopkinton, MA, USA) software (version 3.0.1.2), the hyperspectral microscope imagery was acquired and stored in a proprietary format. Prior to image acquisition all parameters are selected, Binning 1x1, Exposure (auto optimized nominally 33 milliseconds), wave lengths of interest 450-950 nm, and a full region of interest (ROI). The spectral interval or mean band width was set to the minimum of 10nm. After image acquisition the proprietary cube was converted to a series of TIFF files representing each slice of the cube from 450-950 nm at 10nm steps. Using Image J these TIFF files were converted to raw binary format stripped of any meta data and organized into a hypercube format.

The SAM only processing yields a 67.0% successful detection and classification rate on the truth data as reported in Table 11.3. In looking at the isolated effectiveness of the SCM algorithm we see in Table 11.4 there is a low yield of only 8.5%. However, in joining the two implementations the resulting yield combines to 99.2% as demonstrated in Table 11.5.

## 11.7 Conclusions

The combination of utilizing both a spectral angle mapper and spectral correlation mapper proves effective to identify and isolate K12 *E. coli* from a prepared microscopic slide while in platonic form. Processing times for large imagery, approximately 1300 x 900 hyperpixels, remains painfully slow. With recent multi-core desktop processor advancements however observing in smaller sub-images offers excellent results. Even with the processing speed, the turnaround time is better than the traditional lab processing thus this may offer a pre-screening method to be backed up by traditional



**Table 11.5:** SAM SCM integration, full spectrum, detections along X axis, truth along Y axis resulting in a 99.2% success rate.

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
Light Media (A)	14	0	0	0	0	0	0	0	0	0	0	0	0
Light Stained (B)	0	17	0	0	0	0	0	0	0	0	0	0	1
Light Unstained (C)	0	0	8	0	0	0	0	0	0	0	0	0	0
Light Trash (D)	0	0	1	9	0	0	0	0	0	0	0	0	0
Medium Media (E)	0	0	0	0	31	0	0	0	0	0	0	0	0
Medium Stained (F)	0	0	0	0	0	22	0	0	0	0	0	0	0
Medium Unstained (G)	0	0	0	0	0	0	13	0	0	0	0	0	0
Medium Trash (H)	0	0	0	0	0	0	0	14	0	0	0	0	0
Dark Media (I)	0	0	0	0	0	0	0	0	49	0	0	0	0
Dark Stained (J)	0	0	0	0	0	0	0	0	0	45	0	0	0
Dark Unstained (K)	0	0	0	0	0	0	0	0	0	0	32	0	0
Dark Trash (L)	0	0	0	0	0	0	0	0	0	0	2	22	0
Unclassified (M)	0	0	0	0	0	0	0	0	0	0	0	0	0

laboratory findings. Both the SAM and SCM algorithms are easily implemented. Care must be exercised when scaling the fit ranges as noise levels rise and or lighting conditions change.

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# CHAPTER **12**

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## Thinking Transdisciplinarily on a Country Path: Rooting Enquiry and Pedagogy by Learning from Heidegger and the Zhongyong

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*This is a study of how the notion of thinking that Heidegger developed in his writing, especially Conversation on a Country Path about Thinking, can be read through a Confucian text to illuminate transdisciplinarity and how it might be taught. I briefly discuss the eurocentrism of continental philosophy, especially its lack of engagement with and respect for an Eastern philosophical perspective, then give the background of the chosen Chinese text. I next consider Heidegger's position on thinking and draw insights from how we can both teach and enable transdisciplinary relatedness in university students. Learning to think is taken as inherent in the essential nature of humans and is a discovery of our own nature, as well as the nature of Being.<sup>1</sup> This discovery, in What is Metaphysics, and Conversation on a Country Path, offers a way to unconcealment in the onto-cosmology of the harmony of all Being. It is essential to Confucian thought and to the fundamental ontology of Heidegger and, I contend, to forms of transdisciplinary thinking and teaching.<sup>2</sup>*

**Keywords:** Heidegger, thinking, Zhongyong, Transdisciplinarity.

<sup>1</sup> Supported through the generosity of Charles Lam

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<sup>1</sup>I have used 'Being' where I intend to refer to the Being of everything—the being of Being—and 'being' when I refer specifically to being human.

<sup>2</sup>The chapter originally contained Chinese characters to facilitate meaning. These have been deleted due to production issues.

## 12.1 Introduction

The fields of the sciences lie far apart. Their methodologies are fundamentally different. The disrupted multiplicity of disciplines is today only held together by the technical organisation of the University and its faculties, and maintained as a unit by the practical aims of those faculties. As against this, however, the root of the sciences in their essential ground has atrophied. (Heidegger, *What is Metaphysics*, [1], 1949)

The thrust of discussion concerns questions raised by Heidegger as to how we can think about and understand the being of Being—for metaphysics operates in a reality of the being of being human, not at the more essential understanding of Being as a precondition of being. Such an understanding seems more central to Eastern thought than traditional Western. The final section will sketch some ideas on what we might use to develop pedagogical ways for education.

## 12.2 Rooting a Chinese Onto-cosmology

The approach taken in this work is transverse and transdisciplinary, in the sense of redefining barriers and seeking an interpretation that is not only rooted epistemologically, but is ontological and ethical (Kupperman, [2], 2010), and commensurate with metaphoric rhizomatic form. It is in the Chinese philosophical tradition that I see a rooted coherence and worldliness that allow transdisciplinary approaches to flourish and to reveal insights that counteract any reliance on the supposed superiority of philosophical eurocentrism (Jung, [3], 2013). The eurocentric position is typified in Hegel's narratives, *Lectures on the History of Philosophy* ([4], 1892), showing scepticism and even ignorance of the importance of oriental philosophy. Regarding Chinese philosophy in world philosophy, Hegel summarised the *Analects* (Confucius' major work) as:

conversations between Confucius and his followers in which there is nothing definite further than a commonplace moral put in the form of good, sound doctrine, which may be found as well expressed and better, in every place and amongst every people. (1995: 121)

This suggests that the work itself 'would have been better had [it] never been translated' (ibid). Hel categorised Chinese philosophy in world history as 'elementary' (ibid: 125); the contribution of the *Zhouyi* (*The Book of Changes*) as 'superficial' (ibid: 123); and the Chinese composition of five elements of wu-xing (fire, water, wood, metal and earth) as 'all in confusion'. He was no more generous with Indian philosophy.

Hegel's discounting of Chinese thought still influences much of the writing on the relationship of East and West thought, where it is interpreted through a Western lens proclaiming the superiority of Western thought in its analysis

and processes. In Chinese philosophy this lens of logical order is not poorly achieved; rather, according to Hall and Ames ([5], 1998), it attempts an aesthetic order by creating novel patterns. In this order, various the *yin* and *yang*, and the *wu xing* have to be synthesised in order to generate a harmonious whole.

Heidegger was no defender of Western thinking and recognised the role of the language of discourse. He noted that if a dialogue was conducted in a European language (German), the 'languages of the dialogue shifted everything into European' ([6], 1971a: 5) and threatened 'to become planetary' (2012: 137). Indeed, Heidegger is careful both to distinguish yet not impute value in Western and other philosophies, and to call guardedly on examples from Lao Tzu to illustrate his notion of thinking, in counterpoint to dialectic thinking (Heidegger, [7], 2012: 89). Ma ([8], 2008) has claimed that Heidegger cited Lao Tzu in six pieces of his writing and that, in the most extensive of these, suggested that his notion of the Way (*weg*) is synonymous with the Tao (see Heidegger, [9], 1971b: 92).

I approach the project in this article with this warning yet, in the writing of Heidegger and Zisi<sup>3</sup>, there appears a clear commonality of onto-epistemology that goes beyond binary oppositions of humanity and nature, femininity and masculinity, and East and West. At its core, this has compassion for our being as others within the blending of the realities of the existential and spiritual.

In any historical contextualisation, the codification of thought is found in seminal texts, and this holds true in Chinese philosophy. The *Zhouyi*, or *Book of Changes*, is the most important initial discussion of how the way of being in the world is realised, constituting one of the five classics of Chinese thought (with *Classics of Poetry*, *The Book of Rites*, *The Book of Document* and the *Spring and Autumn Annals*).

Confucius' development of the mystical *Zhouyi* through social interaction, rooted in the functionalities of social being based on familial ethics, offers a practical way to be rather than a metaphysics of being. It appears in the *Analects* and, like the *Great Learning*, *Mencius* and the *Using the Centre*, is one the great works of Chinese philosophy and education. These are guides to living life through practical rituals in which relationships can be developed harmoniously with a relational way of being. The *Zhongyong* (*Using the Centre*)<sup>4</sup> was originally written as part of the *Book of Rites*. From the twelfth century onward it occupied a place of prominence in neo-Confucianism as the last of the four texts comprising the foundations of the official government examinations held until 1905. Taken from the *Rites*, *Zhongyong* is a longer, more complex and philosophical book than the *Daxue*. Both deal with self-cultivation, but the *Daxue* is more practical, while the *Zhongyong* is considered

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<sup>3</sup>It is disputable whether Zisi actually wrote the *Zhongyong*, but there is sufficient evidence presented by Johnson and Ping (2012) to satisfy the author of its authenticity.

<sup>4</sup>His book title is translated in a number of ways. Traditionally translated as the *Doctrine of the Men*, the version used here is attributed to Zisi (a grandson of Kongzi), with notes by Zheng Xuan and a commentary by Kong Yingda.

the ontological grounding of self-cultivation and of the centrality of harmony in the Confucian Way.

What is constant in the development of Chinese thought is learning-to-be as virtuous learning; it is about humanity, love, compassion and benevolence (Ren); about living correctly in line with respect for familial responsibility (Li); and, from that core, developing a societal way of being. Correct behaviour, at least for traditional Confucians, is a set of rules governing imperatives with its ethical roots having resonance with rule utilitarianism. Wisdom (Zhi) is relational rather than personal knowing, or knowledge. The relational aspects of Zhi are linked to Ren, the balanced way of being within a community that defines the role, the being, of the person in a specific position. As the *Daxue* evidences, this is rooted in familial relationships in a model for both community and self. This community, according to the *Daxue*, has 'illustrious virtue; to renovate the people; and to rest in the highest excellence'. The learned are wise and exemplary individuals (*Junzi*), people of similar intent and action to the Greek *Phronimos*. Their wisdom is evident in their practice and, in this practice, they become teachers.

### 12.3 Zhongyong

The Zhongyong occupies an essential place in the canons of Confucianism. The book concerns itself with the notion of centrality-harmony through equilibrium. It is about allowing harmony to flourish by personal agency, which is neither necessarily extreme, nor timid, nor passive; it keeps harmony on the right course. It is about knowing when and how to act with long-term harmony of the cosmos as its ultimate goal. Li argued that harmony and *Zhong*, or centrality, 'forms a hermeneutical circle in which the two mutually interpret and illuminate each other' ([10], 2014: 71). It is in this sense that the *Zhongyong* and the *Country Path* are used. In the following passage from the second chapter, the *Zhonyong* explicitly advocates such a balanced approach:

Zhongni (Confucius) said 'the noble man uses the centre. The lesser man does the opposite of using the centre ... Using the centre—this is, indeed, perfection! The people are seldom able [to practice it] for long.' (Johnston & Ping, [11], 2012: 223)

Yet, for ordinary people, the difficulty of achieving this is not removed even when there is intent, as the Way is only achieved by those who have perfection. This comes from learning and being taught, and concerns sincerity, authenticity, honesty, trustfulness and genuineness emergent in enlightened virtues (chapter 21).

There are three critical chapters on learning and thinking in the *Zhongyong*: Chapters 1 and 15, and the resolution in chapter 28. The opening chapter, the most important positioning statement of the book, concerns how one might cultivate oneself, specifically referring to teaching. The first sentence sets the cosmological tone:

What Heaven decrees is called 'nature'. Complying with nature is called the 'Way'. Properly practising the Way is called 'teaching' ... Harmony is the all-pervading Way of the world. Reach the 'centre' and 'harmony' and Heaven and Earth are in their proper positions and ten thousand things will be born and grow. (Johnston & Ping, [11], 2012: 215)

Nature is dynamic, in constant change, due to the interaction of its five elements of nature and their spirits in human beings. These spirits are: wood, which is *Ren* (compassion); metal, which is *Yi* (intentionality); fire, which is *Li* (filial responsibility); water, which is *Xin* (trustworthiness, fidelity); and earth, which is *Zhi* (Wisdom). How these spirits intermingle in humans is a function of individual human natural endowment. Nature is thus joined to virtue 'like waves are joined to the water'. To act in compliance with nature is called the Way, responding in harmony to the wholeness of one's being in the Being of nature and the natural endowment we are born with and, as Heidegger would argue, are 'thrown' into this world. Confucian harmony is understood not only as a state of affairs but as a cosmic and moral order. As Li suggested, as a state of affairs, 'harmony is a continuous process of adjusting differences and reconciling conflicts ... as a cosmic order harmony evolves out of the interaction of various forces and emerges as a guideline for things to operate' (2014: 9/10). Harmony is not sameness, but a creative construction of tensions of being in the world, and cosmic order is cosmic patterning emerging from the Being in the world.

This was at the core of Heidegger's meditative and poetic thinking<sup>5</sup> as it is not susceptible to a direct revelation of nature. This is because we live outside nature as constituted as a whole dynamic system, and inauthentically use it as a resource in our anthropologic way of thinking, in our epoch of technology and its systems manifestation: consumerism. Heidegger did, however, suggest that the essence of Being and beings can be found in *Ereignis*, the appropriating event. This, for Heidegger, was the primordial 'understanding' as the projection of *Dasein*, which is always ahead of thematic cognition. It is knowing ourselves within the otherness of a presenting world, which is outside the language of the rational. This complex but central theme, to Heidegger's thinking, is quite different from conceptual and epistemological cognition.<sup>6</sup> It is rather a process of getting rid of representational modes of knowing. Heidegger explained:

The event of appropriation [*Ereignis*] is that realm, vibrating within itself, through which man and Being reach each other in their nature, achieve their active nature by losing those qualities with which metaphysics has endowed them. ([12], 2002: 37)

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<sup>5</sup>For a discussion of sameness in Heidegger, see *Identity and Difference* (2002).

<sup>6</sup>In his note, Zheng Xuan takes this to be a reference to what heaven decrees for mortals through the spirits of the Wu Xing; the forces of wood, metal, fire, water and earth; their manifestations in being as benevolence, righteousness, rites, trustworthiness and wisdom.

This manner of being may be seen in the embracing of the technological way of being, as recognised by Heidegger, and represents a departure from the Confucian Way although it is returned to through the teachings of those who achieve the Way: sages or thinkers. The exemplars are teachers and, as we have noted, Heidegger took on this guise in *Conversation*.

Turning to chapter 15 of *Zhongyong*, it opens as follows:

The Master said 'To love learning comes close to *zhi*; to practice with diligent effort come close to *ren*; to know shame comes close to *yong* (courage, bravery). To know these three things is, then, to know how to cultivate the self.' (Johnston & Ping, [11], 2012: 301)

Chapter 15 discusses how these three attributes of being can be used to cultivate self and to 'bring good order' to others. The nine canons offer direction and stability to society. Admittedly, these might be interpreted as inauthentic yet, if taken as fundamental ontology as Heidegger proposed, meditatively they provide routes into the social structure into which Heidegger suggested we are thrown. They provide a framework for reflection as well as a structuring of the world. His hierarchical structure follows the process discussed in the *Daxue*. Heidegger has little to say directly about political philosophy, yet in a lecture series ('On the Essence and Concept of Nature, History and State', [13], 2015) in which he developed an ontological understanding of the State and its people, he proposed a relationship much in line with the pragmatism of Confucian thought and suffering the same risk of abuse.

Both passages illustrate an inherent way of realising potentiality, based on capacity to change other entities and ourselves by actions, where the capability can be taught. This has resonance with the Aristotelian notion of *δυναμις*, as both the power and the potential to change. For instance, we need both to want and have the disposition to change the state in which we currently exist, but this is not sufficient. We also need the means to do this, and the two need to be synchronised. To want to be actually better at something is not sufficient to warrant the end one wants. By mentioning nature and Heaven decrees<sup>6</sup> in chapter 1, there is an implicit reference to a range of realities. In chapter 28, the noble man:

Honours a virtuous nature, and follows the path of enquiry and study. He reaches to the broad and great, and exhausts the subtle and the minute. He advances to the farthest point of the high and bright, and fully understands using the centre. He revives the old and understands the new; he is honest and genuine through respecting *li*. (Johnston & Ping, [11], 2012: 353)

This section makes it clear that to study requires diligence, sincerity and authenticity. Further, as will be discussed later, it seems to offer a description of *Homo sui transcendentalis*, to borrow from Nicolescu.

The distinctiveness of the Confucian text, I believe, lies in the centrality of the given Way, a teleology that does not sidestep the notion of being but

locates it in the intertwining of force and spirit in an ever changing cosmos. This centrality is the basis of the cultivated person that is adjusted to fit specific time and situation, so 'he is in harmony with the rest of the world through equilibrium. Or better yet, he contributes to, participates in, and co-generates the grand harmony of the cosmos' (Li, 2014: 80). Such an intertwining embraces mystery and, seemingly the *Zhongyong* sets Being in an onto-cosmological sense. It does this in a form of thinking more akin to the thinking of the meditative and the poetic. It shifts the nature of human being from the individual to the community of others, not in an ontic fashion but as a fundamental way of being, as a fundamental ontology.

## 12.4 Heidegger on Thinking and Releasement

Heidegger focused not on the being of being human, but an exploration of what is the Being ,of everything. This is clear in *Being and Time*, where he suggested that only an investigation into the fundamental ontology from which all other ontologies must spring, an inquiry into the foundational sense of being, yields an existential analysis of *Dasein*. He stated that the 'analytic of Dasein remains wholly oriented toward the guiding task of working out the question of Being' ([14], 1962: 38). He thus conferred a special status on humans to review the nature of Being. This theme continued, and in *Letter on Humanity* he wrote that a 'human being is the shepherd of being' ([15], 1998: 252).

From the quote from *What is Metaphysics* opening this article, it is evident that Heidegger's view was that formalised and structured scientific<sup>7</sup> investigation does not illuminate but adds opacity to the essence of Being. This is because failure to concern the world in its totality for disciplines can, at best, provide only limited revelations, constrained and shaped by the rituals and truth claims of their collective world views. Heidegger argued that it is not through science but an ontological understanding, revealed through mood, that the totality of Being is unconcealed. He began to offer us a distinction between disciplines: inter- and multi-disciplines and transdisciplinarity, which will be developed later. From a Heideggerian perspective, knowledge organised by discipline leads to a refusal of the totality implicit in the calculative and sanctioned thinking of these disciplines.

It is in Heidegger's works after *Being and Time* that I will focus this discussion, specifically his extensive explorations into thinking and willing/non-willing in *Conversation on a Country Path*. In this text, Heidegger offers a process on how we train ourselves to think other than metaphysically ([16], 1966a). This work is an imaginary triadic<sup>8</sup> conversation between a Scientist (disposed to calculative thinking), a Scholar (a metaphysical thinker) and a

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<sup>7</sup>'Science' in the German academic sense includes all natural and humanistic sciences.

<sup>8</sup>Also a translation of Chinese San Ho Hui, literally 'three unite society', i.e. 'triple union society', said to mean 'the union of Heaven, Earth, and Man'.

teacher<sup>9</sup> (the voice of Heidegger as a thinker of thoughts). The focus becomes the understanding revealed in the act of the dialogue rather than what is actually said, not in a linear manner but through hermeneutic circles. This work has seemingly direct metaphorical links between the 'way' of Confucianism and the path.<sup>10</sup> Consider the following extract from the *Conversations*:

**Scholar:**

From this it suddenly becomes clearer to me how movement on a way [*Be-wegung*] comes from rest and remains engaged in rest.

**Teacher:**

The releasement would not just be the way [*Weg*], but rather the movement (on the way) [*Bewegung*]

**Scholar:**

Where does this strange way go, and where does the movement befitting it rest?

Its feel and structure have the appeal of an ancient Chinese philosopher seeking understanding from a discussion with a Teacher, that is, Confucius in the *Analects*.

The dialogues in the *Conversation* have two central themes. The first is the 'open-region', which is both the place of being and where beings can be with one another in a 'topology of being';<sup>11</sup> the second is a critique of the wilfulness of representational thinking and 'a search for a way of releasement from its grip and into authentic, non-willing manner of thoughtfully dwelling within the open-space of being' (Davies, [17], 2010: xiii). This concept, especially the discussion of awaiting rather than awakening thinking, creates a transformative way of thinking that opens a way to understanding transdisciplinary thinking.

Indeed, there is a certain spiritual feel to Heidegger's work that might lead one to consider an onto-theological stance, a requirement for a cosmological entity from whom all is understandable. Heidegger foresaw danger in humanity's reliance on calculative thinking (and its manifestation in machination) that prompted his comment in his 1966 *Der Spiegel* interview, 'only God can save us' (Wolin, [18], 1993: 91).

Heidegger's conversations try to break from the metaphysical and physical to reveal a way of thinking unlike formal metaphysical questioning, but as onto-epistemological enquiry. For Heidegger, metaphysics' failure is that it enquires into the being of human beings, not into the notion of Being—on which being is contingent. For him, this 'Being' is the fundamental ontology representing a thread running through much of his early work and leading to his more

<sup>9</sup>It is interesting that, in *Conversation on a Country Path about Thinking*, Heidegger takes the role of the teacher. The thinker is able to converse not from the grounds of science of philosophy, but from a position I would suggest is occupied and recognised by the great Chinese ancient thinkers by the designation *zhi*.

<sup>10</sup>And, of course, Socratic dialogues.

<sup>11</sup>Heidegger refers to this in his work, *Four Seminars*.

poetic, even mystical, later contributions (Young, [19], 2002). His struggle is hampered by the use of forms of thinking designed for the understanding of being in its enframement of a technological way of being, especially the calculative thinking that encourages nature, including humans, to be seen as resources in the gift of those in power. His insistence on thinking on Being, at the core of our understanding of human being, began to resolve itself in language that is more poetical and mystical to understand Being.

Allowing understanding to emerge, unshackled, from forms of logical, rational investigation opens up new realities and new truths. Moreover, it allows letting the nature of Being of things come into the context of the present as a totality of Being. Heidegger commented that '(M)an is obviously a being. As such he belongs to the totality of Being—just like the stone, the tree, or the eagle' (2002: 31). This thinking is essentially meditative and can be considered metaphorically as 'the activity of walking along a path which leads to Being' ([20], 1966b: 25). Further, it requires a releasement (*Gelassenheit*) of that which enframes and defines the characteristic of man's nature. Release-ment seeks the equanimity<sup>12</sup> to allow technology into our lives yet also resist it. It creates the context of meditative or 'inceptual' thinking (Heidegger, [22], 1999), as an alternative to calculative thinking that defines and measures reality.

Releasement is a central theme for the later Heidegger, and is first discussed in his *Memorial Address for Kreuter* (1996a). Its reliance is on the notion of meditative thinking, which Heidegger counterpoints against calculative thinking. He argued that meditative thinking is as difficult as any other and concerns us in 'what is closest; upon that which concerns us, each one of us, here and now; here, on this patch of home ground; now, in the present hour of history' (ibid: 47). It is about contemplating what this might mean to self and humanity. It is not willed thinking (and it links to the essence of being, as he discussed regarding the work of Nietzsche, 2012), and allows an openness to things; it is open-systems thinking across barriers and between ideas.

This might be reframed as transdisciplinary thinking, as it engenders a comportment, a way of being, that allows the meaning of change to be. As Heidegger reported, 'profound change is taking place in a man's relationship to nature and to the world. But the meaning that reigns in this change remains obscure' (ibid: 55). Moreover, Heidegger referred to this comportment as 'openness to the mystery' (ibid), and that the releasement and the mystery belong together to offer ways to take an autochthonous stand in the contemporary world. This is to think poetically, this is a way that overcomes the representational horizon-bound<sup>13</sup> thinking of the philosophy of our revealed world. Meditative and poetic thinking allows us to grasp the ungraspable

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<sup>12</sup>See Shun (Reference [21], 2014) for a discussion of equanimity in ancient Chinese literature.

<sup>13</sup>By this, Heidegger is pointing us towards that which makes sense of our understanding of the world; a shared background and unquestioned reality of our world that allows communication and shared living.

(Young, [19], 2002: 19).

For Heidegger, education is ontological, to cultivate the student as a learner and human being; yet he was unable to unshackle himself sufficiently from his metaphysical thinking tradition to explore this fully, notwithstanding his valorisation of poetry. It is in this context that I think the *Zhongyong* can shed light on Heidegger's concerns for Being, equanimity and releasement—and learning as an ontological self-cultivation.

## 12.5 Can A Conversation along the Path Change Our Stance on Thinking?

The premise being offered here is that there is sufficient ontological similarity between Confucianism and Heideggerian thinking to warrant meaningful comparison and insight. At first sight this thesis seems problematic. Confucianism is based on a moral praxis that defines human behaviour; that is, a human being is a moral being and, at the same time, axiological and ontological. Heidegger had no place for morality in his ontological thinking and attributed such thinking to the ontic, however both agree on interpreting the subject as a non-autonomous, culturally bound (or thrown) way of being, that can yet change the field of possibilities in which it acts, further, that it is through human beings that Being can be revealed. Moreover, both reject the notion of rationality as the defining attribute of human essence, insisting on the inseparability between Being and essence (Chan, [23], 1984: 194); rather, they stress the primacy of praxis, although in different ways.

Certainly in Heidegger's early work it is difficult to see how the basic premise of Confucianism can contribute to its reading yet, especially in his discussion of being as releasement, in his later work there seems room for the development of a teleological process for revelation to the spirit of the mystical. There are further similarities in the notion of and to the non-willing of open spaces that Heidegger referred to in the *Conversation* but struggled to make clear. There are two ways of cultivating Being: the first is that human beings are the entity for the revelation of Being, rather than any other being (see *Conversation*, 2010: 91); secondly, human beings are central to the cosmos, and the dynamic nature of Being is in the being of change, both inherent and cultivated in humans. Perhaps unexpectedly in Heidegger, humans take the central role in noble mindedness and gratitude. For instance, in response to the comment from the Teacher, the Scholar replied, 'Noble-mindedness would be the essence of thinking and thus of thanking'<sup>14</sup> (2010: 97).

Both Heidegger's notion of Being and Confucian Dao have a unity in the harmony of our being of Being at their core, with Heidegger suggesting that Dao 'could be the way that gives all ways, the very source of our power to think' (1971b: 92). However, unity is fractured when thinking is revealed through methods aligned to different disciplines, themselves 'punched out in

<sup>14</sup>This idea was taken up in by Heidegger in Part II, chapter 3 of What Is Called Thinking?

the die presses of technical-scientific calculation' (1971b: 91); it cannot be conceived only in terms of knowledge as separate entities, as in disciplines. Disciplines structure a world into parts, developing barriers to understanding the whole. Nicolescu refers to this as the epoch of 'technoscience' ([24], 2014), which has resonance with Heidegger's technological way of being where we have lost spirituality in favour of economic powers. Such a way of being is evident in the practices and technologies to which I refer and include the Research Assessment Exercise<sup>9</sup> generally, also annual reviews, league tables and rankings, impact narratives, CVs, performance-related pay, the granting of degree-awarding powers to commercial providers, off-shore campuses, student fees, expanding overseas recruitment, and Public Private Partnerships.

Unlike Gadamer's suspension of assumptions in order to reveal new understanding of an assumed anthropomorphic world view, Heidegger sought harmonic approaches through a hermeneutical understanding of the being of Being as revealed in the notion of Being itself. Certainly, such an approach accepts notions of contextualisation, historicity and disclosure through dialogue, but it also offers different modes of thinking through which this disclosure can occur. In this sense it offers a thinking for different realities, with that of the present through poetic and meditative thinking rather than the dominant academic discourse of critical evaluation. This embracing of thinking as being, not thinking as the basis of disciplines, opens the debate as to what transdisciplinarity is from a different reality; the reality of the non-rational. As Rancière suggested, the poetics of knowledges does not claim 'that the disciplines are false knowledges. A poetics of knowledge is first a discourse which re-inscribes the force of descriptions and arguments in the equality of common language and the common capacity to invent objects, stories and arguments' (Rancière, [25], 2006: 12).

This might be explored through a dynamic cybernetic-semiotic system. The *cybernetic* aspect of modelling amounts to envisaging learner-teacher communication as a whole feedback loop, where the source of information becomes a destination when it is fed back, and where the destination of information becomes a source as it feeds back information to the original source. The *systemic* aspect of this model is that 'control' of information in such kind of system is distributed and resides in the whole system, rather than just one element of it. The *semiotic* aspect amounts to not reducing the 'information' exchanged to discrete elements whose value is governed by a fixed code, along the lines of computing information, but as signs whose meaning is subject to several intermingling constraints (ecological, physiological, emotional, observational constraints) and types of contexts. Specifically, the interrelatedness of the contexts means that emotion arises from the collective results of a relatively large number of processes.

Doing so does not evade the importance of pragmatic things or the notion of complexity in problems, but does decentralise the powerful hegemonies of disciplinary logics to open up problems to investigation by those who are involved. Moreover, this opening up to seek harmony is not an opening up to

passivity but to seeking cosmic patterns emerging from the myriad things interacting within the universe. In seeking harmony within the cosmo-ontological nature of our being, we erect a platform for the discussion of problems and the realisation of forms of understanding, enquiry and resolution, which are different in form from the fragmentary issues of disciplinary and calculative thinking.

The relationship between calculative and knowledge produced in the disciplines is not clear; for example, does this mean that *all* work produced in each and every discipline is in some way flawed. With regards to the next stage, interdisciplinarity, there is a massive problem with the notion of combining qualia from different disciplines in a harmonious way. With the highest level of all, transdisciplinarity, has to be framed in foundational terms and not in some sense as an extension, completion or perfection of framings at lower levels, though one may have to go through the lower levels to get to the higher levels.

Heidegger argued that it is not through science but an ontological understanding, revealed through mood, that the totality of Being is unconcealed. In the first instance then there is a need to develop a theory of interdisciplinarity, with the understanding that it is inevitably incomplete. This requires a move from manifest phenomena to underlying generative mechanisms and structures. The argument from disciplinarity to interdisciplinarity and thence to transdisciplinarity involves a series of ratchets or steps. However to get from multi-mechanisms to interdisciplinarity and thence to transdisciplinarity, we have to add considerations of *emergence* to those of complexity. Briefly an *emergent* level of reality is:

- i) unilaterally dependent on a more basic one;
- ii) taxonomically irreducible to the more basic one; and additionally,
- iii) causally irreducible in the domain in which the basic one operates.

If such emergence is involved, then the characteristic multi-mechanisms of open systems will have to be studied in a multi-disciplinary way, i.e. by (or from the perspectives of) a multiplicity of disciplines. If in addition to an emergent *level*, a qualitatively new or emergent *outcome* is involved in the causal nexus at work, then the knowledge required can no longer be generated by the additive pooling of the knowledges of the various disciplines concerned, but requires a *synthetic integration, or genuine transdisciplinarity*. This last then is not reducible to disciplinarity or interdisciplinarity, though it is emergent from them. There is a radical incommensurability between disciplinarity and interdisciplinarity, and interdisciplinarity and transdisciplinarity.

In so doing, one's expectation of oneself and of others might change, defined in terms of their calculative thinking of having, desiring and taking. Problems are not different in terms of the current absolutists' presence, but are conceived in their historical context and in terms of others' contingencies and their world view, whether animate or inanimate, occidental or oriental. Such an approach

does not look to hegemonies of knowledge to redefine problems away from their context, but to locate them within both a local and global context and use the learning from them to inform a wider engagement of dialogue; one of emotional, spiritual, tacit, contextual, traditional, tribal, imaginative, patterning, reflective praxis rather than one based on transcendentalist thinking.

So, to poeticise graduate thinking, our pedagogy needs to respect the onto-cosmology of our being developed through different modes of thinking. Our pedagogical practice would be transformative, transdisciplinary and realised as a dynamic semiotic system.

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# CHAPTER **13**

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## Transdisciplinary Education: Self Knowledge and Quality of Being

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*In this chapter we reflect about subject education and propose a transdisciplinary alternative as an essential and desirable prerequisite for a conscious and responsible living. With most of the emotional and intellectual honesty available to us we are able to explore different aspects of knowledge from the interest that corresponds to the opportunity of being alive.*

**Keywords:** Self knowledge, quality, consciousness, education, subject, trans-disciplinarity, corporality.

Binary thought is one of the possible ways towards truth: The false appearance of truth is a useful passion. The imposture of binary thought: Not keeping it's place. I don't pretend to demonize binary thought, because it already is diabolic and extremely useful. I simply desire, to locate it in its right place<sup>1</sup>.

(Nicolescu, 1994: 248)

### 13.1 Background

Academic thought in the modern occidental tradition is founded in precepts, uses, and methodology apparently homogeneous and well founded for scholars as well as followers of the academic route. This situation was consolidated based upon the sumptuous achievements that the pairing of science-technology has offered humanity in the past three centuries. In this point it's essential to

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<sup>1</sup>All translations to other languages are ours.

remember that modern scientific thought is not built in one piece, beginning with the existence of a clear distinction between natural and social sciences, also between humanistic and artistic thought. In the other hand,

within each of these fields there is multitude of methods. When we acknowledge these referred singularities we pose that most of these schools and fields belonging to the modern occidental academic tradition share the rationalism positivist fundaments.

The objective of modern science could be identified with the search for truth and the infallible explicative models and predictions which approach reality. This is accomplished according to their advocates, by means of “objective” systems that exclude opinions and “subjective” appreciations, because it’s explicitly established that the subject must abstain to involve his emotion or personal values, as to prevent contamination by his prejudgments. This is the “meticulous and impartial” analysis of observations and measurements. The unrestricted adherence to these methodological foundations of rationalism-positivism became the unequivocal guarantee of objectivity.

Within the epistemological scenario of modern academic thought, as we have describe it, we represent the person that investigates and thinks the world as: a) someone who develops a neat relationship with the world (applying experimental or observational rigor) through a scientific design. This aspect is complemented by: b) an erudite domain of theories, previous evidence, and explicative models referred to the studied process.

Science does not require veneration or repudiation, but it requires an understanding of itself that will unfailingly allow seeing the urgency of some changes. Science is a path in the search for a more honest and valid relation and comprehension with reality. This is a shared purpose by most scientists. But this intention has to be questioned, as Einstein did when he asks himself “To what does produced knowledge serve?”<sup>2</sup>

Given the dominant epistemic practices, with their obvious shortcomings, call for answers of different scope to the given situation, either in terms of personal wellbeing or related to the social group of which we are part. There are dilemmas in research systems, such as theories that hide established values instead of directly observing reality within a rigorous and reflective experience. This happens especially in the study of life and its physical, social and psychic manifestations: some examples would be: violence within society, preponderance and prerogatives to capital instead of labor; inadequacies in curricula for medicine and biology; injustice right and left, etcetera.

Why is it that in the midst of so much “progress” an “efficacy” this happens? What happens to the person’s life? It is clear that possession of wealth

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<sup>2</sup>Why is it that talented scientists usually get interested in knowledge theory? Isn’t enough work to be done in their field? I often listen to this comment from my professional colleagues; or rather I feel that in the case of many of them this is what they feel. I can not share this opinion. When I think that most of the more capable students that I have known while teaching—for example those that distinguish themselves for their independent judgment, and not only for their ability—have always had a living interest for the knowledge theory” (Quoted by Holton, 1988).

and power does not translate into happiness or true satisfaction<sup>3</sup>, an issue that must be a central objective for education.

## 13.2 Interior Knowledge

As we have been constructing until now, we will keep exploring the desirable condition of keeping our investigation sufficiently open. Our intention is to provide elements to strengthen the person's relationships in the context of the society in which we live.

The investigation that is concerned with self-knowledge and human being evolution has been disqualified in some epochs as "esoteric" or "mystic", without considering that it refers to introspection, to the cultivation of knowledge about what is subtle and intangible. To what is alive in our experience and is central for all that is revealed exteriorly in our thinking and doing. With the practice of attention and contemplative attitude it becomes possible to achieve an observational quality in which "I" does not interfere as an illusory element usurping the totality of being. In this practice the disjunction and opposition of subjectivity and objectivity are carefully attended, producing a creative transformation of the "crystallized ego"<sup>4</sup>.

The path of interior study<sup>5</sup> is not related to any spiritual or religious ideology, it is an epistemic awareness essential for the life of knowing that is not so attractive for most persons because it implies work and rigor and we live in a short-term vision utilitarian society. It is much easier to develop exaltations and hoist flags, because once we are identified with it we feel protected and as consequence fundamentalisms of any denomination are born. That is why the practice of staying in front with interiority (observing oneself), as we propose, is transnational and transreligious.

Reason, which is predominant in modernity, produced the rationalization culture that confused "sacred" with "belief in a particular religion" hence it rejected the sacred. However, sacred is what unites or links (*religere*), it is as Eliade says, what gives us the consciousness of living in the world (quoted in Nicolescu, 2009: 60). This is why, when transdisciplinarity unites subject,

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<sup>3</sup>It would be worth considering the need to change the 'Gross Domestic Product' by 'Gross National Welfare' as proposed by the Kingdom of Bhutan. (<http://www.bhutanstudies.org.bt>) (Amartya Sen)

<sup>4</sup>Morris Berman in his book *The Reenchantment of the World* poses: "... "for the infant subject and object are almost completely undifferentiated"... and continuous: "Romain Rolland, in a letter written to Freud in 1927, denominates this phenomenon "oceanic feeling"... at this stage, pleasure of reality is equal to knowledge of reality, fact and value are one and the same thing" and he concludes that "... [in] the third year of the infant, a gradual series of developments finally produces a discontinuity that builds and crystallizes the ego". (Berman, 2001: 156).

<sup>5</sup>More than the study we mean the care of a relationship with the being from attention. Wich must be developed with as little involvement of intellect as possible. It is necessary to practice every day and frequently this "disappearance" of the "ego" by staying in front of all impressions that are received in a given moment.

objet, and hidden third<sup>6</sup> it considers the “sacred” as a part of a new way of being where Reason is not excluded.

### 13.3 Examples of Inoperative Solutions

Humility discourses are a source of pride in the vain and the humility in the humble. So those on skepticism cause that believers affirmation. Very few are the humans that speak with humbleness about humility, chastely of chastity, few speak doubtfully of skepticism. We are falsehood, duplicity, and contradiction only; we hide as much as we lie to ourselves.

(Pascal, 2008: 377)

The sense of urgency makes us feel and think, or think and feel, “That we have to do something”, and this ends being only good intentions. The dual thinking reappears seeking to solve by confronting, without having created the necessary space for the equanimous manifestation of a third influence that does not eliminate, but rather unites, the apparent contraries. That is why Nicolescu says: “The crazy accept contradictions without understanding them, while the wise accepts them having also the embodied vision of its unity. So it is understandable that the contradictory vision is often perceived as a destabilizing thought” (Nicolescu, 1994: 45).

In this sense the dual thinking, exposed in the form of opposition, produces approaches like these: “I’m going to stop thinking and needing”. This attitude is almost natural in our times where self-knowledge is neglected. But a calm approach towards the entrails of my processes of living and knowing clears the fact that the relationship with oneself is overlooked. We are almost blind to our value system and believe that actually determine our thinking, in a process where we overestimate our true capacities making us slaves of our mental habits. A follower of the path of internal inquiry, that is nurtured by a “being aware”, actively explores and makes use of tools related to an “activated awareness of knowing” because he has recognized the strength of desires and concerns. In that case, he admits by proper experience that the search for freedom “is not for oneself” but “of oneself”.

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<sup>6</sup>The transdisciplinarity methodology pose by Basarab Nicolescu, comprises in its doing three fundamental pillars: i. “Ontological”, pose that there are different discontinuous levels of reality ii. “Logic” poses the included third logic as an alternative to the lineal Aristotelian logic (see below the main text) and iii. “Epistemological” which speaks of the complex dimension of articulated space and hypercomplexity in the levels of reality. The cognitive cosmic stage in which this methodology “lives” implies the existence of a “transdisciplinary object” with its levels of perception, and also between levels of reality on one hand, and between levels of perception on the other. There is an “space”, “zone of absolute transparency” or “no resistance” as a space of interrelation and care in our experience of living between universes of the transdisciplinary subject and object. This non resistance zone extends and widens through the transdisciplinarity attitude to form and nourish the “Hidden Third”. The existence of this Hidden Third as a fluid space is the expression of “the sacred” in the living and knowing process (Nicolescu, 2001, 2014).

So again, when we say; “I want to undertake not to do”, if I make a stop in my research, with a rigor coming from honesty, I can recognize the limitations that operate within me as a result of the interference of desires associated to patterns with which I am identified and show every moment. So, when we say, or rather it says itself in one: “I am going to change the world”, what we are really saying is: “I don’t accept things as they are”, “I don’t like them”, which again is the result of dual thinking between our ideal and what we perceived as inadequate.

Corresponding to this state of affairs where our thinking and our actions come from an ego assumed as the “totality of myself” our “external” investigations such as science and technology – even art–raises “the conquest of nature and the world”; not to belong to them, not to be integral part of something much bigger, but rather be one that dominates, the one who indicates “what is to be done”. For the one who only studies what is outside, without attention, with intellectual judgment, there is nothing bigger than his personhood; the belonging and unity experience would convert you in a servant. We are talking about someone who serves something bigger than ourselves, who does not feel as a conqueror of nothing or in any case who is not a slave of something that has little value in relation with life’s value itself. The honest acknowledgment of this state of affairs transforms from its root our attitude that claims to “investigate and change the world”, so that it gives sustenance to the attitude of service and presence, which are fundamental qualities of my relation of knowledge towards the world and myself.

Another example in this matter is when, with skeptical attitude, we declare that “we are destroying life’s viability on earth” and jump to the conclusion that this is to be solved with ecological and or sustainable actions. This is another manifestation of dual thought with the lack of interior vision. In our experience the unviability of these answers originate from the established values that I don’t recognize in me but within the difficulties that we experience as individuals and humanity have its support, since they are not being recognized they exert their undesirable consequences in my own thought. True values will emerge as living tools for a respectful and viable way of thinking and doing when there is an appreciation of life from the experience of what I am at this moment in my totality. This process is not possible when the rational intellect works isolated from the rest of the Being: “Which is the light that really helps us to see? Physical light helps us to see exterior objects for survival. Interior light lightens our vision and allow us to live” (Nicolescu, 1994: 64).

### **13.4 Actual Values Set and Possibility of their Transformation**

alues–those forces that sometimes are hidden desires or almost invisible for the intellect–operate from their ignored existence and determine in an automatic

manner what to procure and with what to get involved. This “apparent” lack, a type of invisibility, where the values are not established by the scientific method not even for the thought in general, are not the result of a personal decision. They create and consolidate on the social environment, as living influences, the formal and informal education.

The values may be related with the moral and ethical aspect of conscience. In the Western World they were reinforced by catholic and other religions as paradise reward and inferno punishment. The moral aspect of conscience is central in this area of the world, while in Orient—including Asia, Africa, Oceania, pre-colonial America, and even Europe before modern positivism—is more conjoined with consciousness as a living experience in the body. This relation exists in different intensities and levels.

Levels of consciousness, related to how high is the level of consciousness of my existence, has a decisive influence on what ethical values are established on the individual psyche<sup>7</sup>.

Let’s see the crudeness with which Søren Kierkegaard exhibited the possibility of human beings: “The best that humans are able to realize is their nullity” (Kierkegaard, 2004: 110-111) This coincides with the approach of Hegel when he exposed: “The consciousness of life, its existence and its action is only pain on this being-there and it’s action, since only here is that consciousness finds its contradiction of the essence of consciousness and his own nullity” (Hegel, 1966: 82) It is unlikely to deal creatively and with a transforming perspective a problem that is not addressed without prejudices or identifications<sup>8</sup>. The values set with which I interacted in the world lead me to instantly determine a crisis as a “problem”, qualifying this state of things as negative and therefore to be “solved or eradicated.” All this happens without the awareness that I act this way moved by cultural identification with inconsistent intellectual patterns. For this is one of the ways to get into other aspects of knowledge, beyond identifying the problem and pose “my solutions”, this is to “suspend” mechanical thought reactions and going into a state of questioning (interior and exterior) to perceive that maybe the problem is really a paradox that requires another type of comprehension. This will be almost impossible if I present myself with; “I think, I solve”, every time that the first person singular is called, implicitly or explicitly, I am affirming that I know who is that I am, in such a case the emergence of the important question that would open space for a solution that would manifest in another level of reality for the participation of the Hidden Third is inhibited.

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<sup>7</sup>On this culture plays an important role, for example, on the Spanish language the word for a moral aspect is “conciencia” while for consciousness it’s “consciencia”, There’s only one letter of difference that very few people are aware of. Both aspects, the moral and self awareness, are closely related.

<sup>8</sup>No identifications relates to detachment from ego and ideas that deal with situations from prejudices and dogmas.

## 13.5 To know

Why involve the subject in the life of any person, researcher, worker, farmer, scientist, artist, or whatever? The acceptance of not knowing “who I am” Is necessarily the beginning and end of attention training that could evolve to different levels, that are not, in its manifestation, what we could wonder. No one is capable of fully imagining what is not known. What is imagined can never be live experience; imagination is not capable of producing the flavor that has not being tasted. These two paths of knowledge outlined here, external and internal, are not antagonist, but complementary. For whoever is interested in experiencing the gift of life as a human being the shortcomings in the rational Cartesian thought are evident.

To “know oneself” does not have any relation with “explaining oneself”. To know myself in terms of my emotions begins with the question: who is this I? Which appears Implicit when voicing the word mine. The question is, who says mine? Who is this owner of the analysis? Is it the intellect usurping an authority that could not be entitled? Silence is the space that does not appear with more noise, with additional thoughts that will not procure a space where the concepts are unnecessary. That is why Nicolescu poses “Not to confuse rigor with exact definition. An excess of definitions kills real rigor. That is why poetic knowledge is more rigorous than scientific knowledge” (Nicolescu, 1994: 137).

Engaging the subject in the study in vivo is a matter that may not occur at any other moment that is not this moment. It demands for an attention quality that does not happen automatically. Training is hard, rigorous and honest; it often takes years of dedication. The change towards the required level in order to get the ability to see is not achieved with improved external instruments, nor is it with dogmatic or exalted acceptance, but only with the objective and persistent realization where “my” better integration with the “all” depends on my capacity to be free of “myself”, these set of small “I’s” which do not know each other.

Science without religiosity is blind, it does not get the subject involved, but nevertheless, religiosity without science is also blind: everything is within the subject.

## 13.6 Who am I?

It is inevitable to realize the importance of knowing WHO I AM. To know oneself is a recurring invitation in different cultures. In the study of this phenomenon that is changing constantly is where you can see the powerful force that definitions have and the damage they cause to an “in vivo” investigation. The same cannot happen when instead of letting me flow I keep a stagnant form of the “truth.” Flow is directly related to my capacity of accepting, because the moment I resist, I suspend flowing.

Is the desire to transcend a state of mechanical associative thinking or an act of free will? Or is it a gift from a superior order? Whoever has gotten involved in this “seeing himself” know some of his own traits. Here we are taking about a Freedom that we have to write with capital letter. To stop being reactive—or reactionary, others say—, is to live aware of my life; it is to recognize me in everyone and in all. Here is where the path begins, path that is made by walking it.

The “me-I” of mechanical reference is what I am; or rather what I am being, and requires to be actualized. This is the vicious circle that cannot be understood by the intellect when it works isolated from the rest of the Being. Science and art that depend on the state of the being art transdisciplinary, and Basarab Nicolescu’s<sup>9</sup> methodology is adequate if applied “in-vivo” as he indicates. The objective and impartial observation of what I am being before the mechanical reaction—automatic— pretends to correspond with the image that each one has of him, of something that we don’t know properly.

Transformation corresponds to development of human being produced gradually, it is not produced by “I” from the will to “do”. What is my responsibility? What to do or not to do? Different traditions use the metaphor: “prepare the ground” (pave the way), because it is considered that planting will only prosper in a qualified field. To know the field is what may be accomplished staying in front of what is that I am being, if what is seen does not causes pain and maybe even terror means that the seeing is not open enough. The work to “see the interior” produces results that may not be explain by dual logic, but it could by Liquid Logic,<sup>10</sup> and the logic of the included third<sup>11</sup> (Lupasco-Nicolescu, logic).

Dedication and rigor are to be exercised effortlessly. This is because when we denominate, evaluate or judge we disrupt the observation, these dispositions close the door to the encompassing perception and prevent us from living the moment in its fullness.

With a trained attention the conjugation of the first person singular could become a universal plural. This work consistency should be such as to allow the formation of a capacity for consciousness and to be capable to stay in front of the experience of being alive. This is impossible with a subjectivity supported by an immature reactive emotionality, or by judgments that take a permanent adjective form as a substitute for a vision founded on genuine interest and direct appreciation. For example when we say to someone; “look: how pretty”, instead of only saying; *look*; or better yet inviting to share the scene.

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<sup>9</sup>See note 6

<sup>10</sup>In perception there is no game of truth like with mathematics. . . in perception, all truth is circular or provisional. . . in this type of truth we don’t have the marvelous certainty that we find in dual logic which would be a “a masked belief of truth”. Perception is essential in liquid logic. Water flows. Water is not definitive or has hard consistency. It adapts to the recipient in which it’s pour. (De Bono, 1996).

<sup>11</sup>The included third unites the opposites A-no A, it is located in the field of logic; The hidden third unites Subject-Object and a-logic.

Life as an irreducible experience, could get to be appreciated objectively by an awakened being that recognizes the shades of grey that actually form a reality that is not only formed by blacks and whites. *Third included* logic corresponds to the reality of life better than a logic based on the “excluded third”. When the relation with the existing goes beyond the prejudices or judgments the borders that divides what is there vanishes.

## 13.7 Hidden Third

The sacred in everyday life can emerge when the respect for what is there does not happen forcedly. The hidden third appears through the work of internal research, with affectionate rigor. This work is done at different moments and not only at moments that are considered “well-timed.” In the constant process of unmasking himself. The more apparently inadequate these moments are, the more relevant they will be for honestly recognizing me.

In the field of science it is important to remember what Einstein said in relation to a religious feeling:

“[...] An astonishment from natural law that produces ecstasy, which reveals an intelligence of such superiority that, compared with it, all the systemic thinking and acting of human beings is totally insignificant reflection. The most beautiful experience we have at our disposal is mystery. It is the fundamental emotion which stands at the cradle of true art and true science. To know that there is something impenetrable to us that really exists, and manifests itself in the biggest of the wisdoms and the most radiant beauty that our slumbering faculties can comprehend only in their most primitive forms—this knowledge, this feeling, is in the center of true religiosity. In this sense and only in this sense, I belong to the group of men devoutly religious.”

(Einstein, 2000: 10-11)

In this inner search the question, as has been expressed by William Seagal is:

“Who am I? When I see my face, or the other person, one asks himself what is behind that face. Who is that I? We change. One moment I like you; in another moment I don't like you. I am in favor of something. I am against something. Here is this estranged human being. This is what I look for. To find what is below that surface. What is that is not subject to change every moment”<sup>12</sup>

(quoted by Gonzalez, 1999)

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<sup>12</sup>We recommend the reader review the excellent text by William Seagal, and which we understand is one of the authors with greater honesty and sensitivity that have approached the work of self-awareness (Seagal, 1987).

The Hidden Third is essential to unite the spiritual, psychic, biological, and physical levels of the subject with the object levels that are present in nature and society. Knowledge is transformed into understanding, that is, the reunion of knowing and being that gives meaning to human verticality in the world, an attitude that goes beyond indifference and is a permanent vigil.

### **13.8 Attention**

The main tool we have as humans is the “Attention” and here we have once again the testimony of William Seagal: “Caring for the capacity of attention is probably the most important thing a human being can do, because with developed attention we can be closer to knowing who on” (William Seagal, personal communication). So in any human activity whenever we apply a good quality Attention it is possible to experience Love, for as the Rig Veda says: “In the beginning there arose the love” (anonymous c. 1700–1100 BCE) and in the Gospel of John it is stated: God is love and he that dwelled in love dwelled in God and God in him “(1 John 4.16; Latin American Bible, 1997) We can, in short, work daily towards an openness to reality without the barriers of self-importance, or the fears and desires that exist while the ego holds sway in our lives.

To Research with my whole being what I am being is like opening myself to reality while exercising a kind of attention that is gradually less affected by the interference of desires and fears that occur when looking for recognition. But the research cannot come to life if I try to fill the gap of the lack of awareness with flags that prevent me from keeping my interest. Interest is the form that takes a question with capacity to generate change. The question appears in the form of interest and it becomes an avenue towards the complete experience of life when It’s not just formulated with words. When I am interested in a flavor, I won’t ask my own bite with words: what is your flavor? What I do is that I pay attention and the answer will be likewise, with a flavor that could not be received fully if the interest doesn’t have room.

The answers that take the shape of a living experience are the best nourishment for a human being. It is not possible to be alive for a single moment without impressions; thus, the quality of this essential nourishment is involved in the soul’s health and the possibility of openness until finding the confluence of the eternal moment in our becoming.

### **13.9 Absence of Knowledge and Relation Human Being – Nature**

Human history may be defined as a process of progressive diminishing of conscience to favor increasing the power of Humans over Nature. This evolutionary entropy is the foundation of our destruction.

(Nicolescu 1994:200)

Knowledge is generally understood as data accumulation and the capacity to discern this data is named intelligence. This approach is very different to what Edgar Morin poses from a complexity vision: “there is no knowledge without knowing knowledge”(Morin 2006: 34) Where Knowledge is implied and actualized in the relation between humanity, society and life in the world.

Within a reductionist vision the opinions, declarations and the psychological needs of the possessor of “knowledge”, produce destructive results; this is because the forces governing individual behaviors as well as society lack affection. The predominant way to relate to life is with a conscience quality that may only produce what is in sight.

If we observe what happens around us it is easy to realize what men’s behavior is (it is important to remark that it is mainly male gender)<sup>13</sup> in relation with nature: it is a perverted, binary game; to destroy then rebuild, as if planet Earth and humanity could endure ad eternum such aggression. The list of such aggressions is vast, and it signals that the scientific- technological achievements have not being in accordance to procure a provided life corresponding to ancestral ideas of coexistence and respect, supported by the acknowledgment of the sacred.

May this binary vision be recognized as knowledge? Not from a complexity and transdisciplinary perspective that is part of the forces that, although precarious, contribute to prevent the kingdom of entropy in the universe.

But still, the counterparty to mechanical destruction is increasingly feeble; there is not enough conscientious work on this planet<sup>14</sup>, which is subject to absurd values of power as an expression of greed. This is why it is necessary to not confront what we are being as to discover paths of honest contribution in a transdisciplinary sense for the benefit of our planet; in a more ample perspective considered “Mother Earth” by those who have established a less damaging relation with the environment of which we are part of.

## 13.10 Science that Depends on the State of Being

The scenario described above reveals an image directly related to a partial comprehension and a behavior that is totally unrelated to Being, in other

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<sup>13</sup>In modernity the introduction of the anthropocentric paradigm actually became androcentric paradigm.

<sup>14</sup>Although from the so called “new age” perspective there has been a proliferation of actions in favor of a new relation with nature and among humans, this perspective is still anchored in a dual vision of reality. When using the word secular we would like refer to a form of being the world that is moving away from sacred, that looks for what is mundane in the sense of what belongs to what is not “relegated” as part of the living net work. This living within the embodied question of what is that I am being we call a spiritualized life.

words: totally secular.<sup>15</sup>

With the tools available to the intellect we cannot accomplish a real change of values—since in itself it is isolated from our totality in which we also have emotions, body and their relation. Pure intellect poses solutions that do not take into account the Hidden Third they are confrontational approaches; a real relation with conscience will only happen as an experience when you are aware of your own life. This means including more of what I am being.

Capacity of self-knowledge is different to the capacity that enables us to perform a task; this capacity does not show from one day to another, neither is it materialized with live experiences when incorporating the concept to a language. It is increasingly frequent to incorporate in intelligent conversations these ontological matters. But if we are not to be contempt by just reading the menu, we could realize that the path to self-knowledge is a science, an art for which formulas or recipes are not enough.

To establish a relation with oneself—and through this with the universe—is a comprehensive phenomenon like when we can testify that the light of all stars and the scenario that they are part of can enter into the eyes, our little eyes. We also understand this when we realize that each one of the living cells has a connection with the whole universe. This offers a comprehension of cellular differentiation and all phenomena related to life as a representation of a superior order; such coherence is not associated with stricture, meaning that it is coherence in all directions, upwards, downwards, but also horizontally; this is to say towards incarnation and the network of our particularity and historicity.

The sacred allows an encounter between the ascending movement and the descending one of information and consciousness through the levels of Reality and levels of perception. As Nicolescu states “The flow of information that traverses in a coherent form the different object levels of reality corresponds to a flow of conscience that traverse coherently the different levels of reality of the subject” (Nicolescu 2009,58). Such encounter is the irreplaceable condition for our freedom and our responsibility. In this sense the sacred discloses as the ultimate source of our values.

Freedom with coherence is an attribute that allow us the connection with Universal Consciousness in a humble way, then it is possible to affirm: “I know It, but It’s still a mystery”. To relate with this totality is essential to be present, a presence that includes more parts of my Being (with capital letter). This is the way that we attain the possibility of preserving human beings.

Manifestation of presence is a personal value that no machine can measure; there is no counter capable to evaluate these accomplishments. This is a great difference among many others, with accomplishments that may be accounted for.

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<sup>15</sup>When using the word secular we would like refer to a form of being the world that is moving away from sacred, that looks for what is mundane in the sense of what belongs to what is not “relegated” as part of the living net work. This living within the embodied question of what is that I am being we call a spiritualized life.

Yet the biblical passage in Mathew 7:16: “By their fruit you will recognize them. Do people pick grapes from thorn bushes, or figs from thistles?” Could spread and then our science, “truth controller”, that implicitly backs decisions that have produced the situation humanity is living, would recognize in its foundations the necessity of inventing concepts manifested with neologisms.<sup>16</sup> So then, to initiate the approach to self-knowledge, an essential part of a return to a quality of being which we lack, but that we blindly attribute ourselves, would be the condition we need to open ourselves to know the world.

How to pose affectionately and coherently to science world this state of things? For us an answer is; attending to the need of a transdisciplinary education through a process of self preparation essential for each human being and that may allow enrichment of whoever teaches or investigates when may trespass the reductionist epistemic barriers.

To be in touch with the actual present is the secret to have creativity, of meaningful life, no coercive consistency and tending towards freedom. Coherence creates order in a natural way, it is not necessary an individual growth development preprogram with explicit recommendations, this are unnecessary. Education without inner work would produce more of the same, no matter what flags are hoisted (justice, freedom, dialogue, new paradigm, etcetera).

### 13.11 Towards Transdisciplinary Education

We as humanity find us in a definitive period to obtain our survival. An irreducible gap between our technological-scientific enormous capacities, respect to the thinking quality and human being actions, are producing serious consequences for our living and environment. As we have pose this situation has its foundation in our thinking habits that assign a privileged and dominant role to the intellect, assuming that our ego has a control on what is that we think. Via formation of individual by family, community, media and formal education of the individual we reproduce these customs consciously (this is rationally) but mainly in an unconscious form.

Actual education has as main objective inculcate the desire to possess reality control and accumulation of goods, which is considered success. There are disguises that hide the fund truth it is only at rare occasions that we find a professor or investigator that finds and question dogmas, no matter how well established they are so to get moving our human species again. XXI century education, as Jaques Delors indicated in his UNESCO report, would have to be supported in four pillars if we want to transform our present condition. Learn to know, learn to do, learn to live together and learn to be (Nicolescu, 2001: 93).

Modern society has generated educational systems allotting them responsibility to form children and young assuming that knowledge is to be created

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<sup>16</sup>When neologism takes the place of real understanding they become an obstacle for this. (new concepts and neologism would lead to an analysis of the logic of language and could strive us away from the actual described phenomena)

in disciplinary specialist centers, based on explanatory models, theories and information that are to be transmitted more “effectively” to the students. In parallel, we accept that the most outstanding students should continue on a rigorous process of overspecialization to become academic career, responsible for the “relevant knowledge” that guides the destinies of an ignorant and receptive humanity. In educational system it is a pattern that these overspecialized university people be in charge of generating frontier knowledge that will illuminate the path of teachers, who would be in charge of transmitting it to the students in training.

Even though the overspecialization model is accepted as a kind of dogma of “proper” formation to become good citizen, from a more open and transdisciplinary perspective we can realize that there is an experience universe and knowledge sources, but mainly of wisdom that happen to be essential to complement, deepen and enrich our daily process of Being and Knowing. Some of these sources of transdisciplinary self<sup>17</sup>-formation are for example; everyday and familiar experiences, mainly those transmitted by grandparents to their descendants; female intuitive and heart knowledge; tales, myths and legends; experience and wisdom coming from our own body and its relation with knowledge that also live and recreate in nature.

There are also countless sources of information, distorting patterns and models of proper human development as video games, consumer marketing, drugs and many more addictions, an avalanche of “entertainment” sources such as; cellular phones, TV, shopping centers, etcetera. There are many aspects of this human’s formation and deformation system that promote a departure from care with attention proper of introspection, contemplative attitude and self-knowledge. Essentially this occurs when going into a virtual experience in front of a screen that exiles us from our Being-body<sup>18</sup>.

The usual manner of always going to outside performance to conquer and dominate the world is founded on the Cartesian idea of ontological separation between mind and matter, what is derived in a call to attend our mind, like if rational process would be sufficient—exclusively center on “objective observation—to exactly and positively know the world until the error is eliminated. Francis Bacon one of the fathers of this rationalistic-positivist tradition openly posed that we have to be able to corner the nature so to extract at all costs its laws and regularities necessary to create our explicative models (Berman, 2001).

Such action, as we understand it, is in the root of our civilizing crisis that

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<sup>17</sup>It is essential to introduce the Morin’s self notion, as an expression of this endogenous personal work that activates when opening mi thinking to my own being in knowledge. Morin also recommends to include of this “auto”, “eco” meaning a constant process of being and knowing that is immersed, busy; taking care of their “oikos”, ie of our world that is our home, house ok knowing and being, hat is why is more appropriate to say; auto-eco-formation(not training) (Morin 2002, 129-136).

<sup>18</sup>In our work at the “Centro de Ecoalfabetización y Diálogo de Saberes” Veracruzana University, we have chosen to name this “living the experience” being-body”, to highlight the fact that fragmentation in two words of “being” and “body” is an artifice of rational mind (Vargas and Rehaag, 2012).

explains in part why is that we're driving the world to destruction as well as humanity, same that has happen to millions of species that homo erectus, no sapiens, has exterminated on past three hundred years.

From a reductionist point of view about education we assume that learning is a quality of rational mind, a brain process that requires a kind of training a type of cerebral gymnastics, this is to say that just being exposed for years to theories and explicative models, we will be able to dominate this art of practicing autonomously rational-positivist specialized thought.

In this writing we have presented, from the transdisciplinary perspective of self-knowledge, what is that constitutes the central task for human living and thinking. When we observe with interest humanity situation in our time, we see that as society we have being unable to propose educational processes, that would allow consolidating us as integral human beings, where our staying and knowing in the world is founded in our quality as human beings. This profound lack in the subject that receives first and then gives the type of "education" is the result of a radically fragmented knowledge that believes to know more but about increasingly less.

How to help the "other", what is the teacher's role? The pushing relation, or in other words it forces or pretends to manipulate, does not work in a sustainable way<sup>19</sup>. In the other hand in an equilibrated relation, one opens to the other so freely takes, without abusing, what is required. This does not happen if the other asks for more than reasonable and in a bad manner, the one that forces the relation would spoil the relation flow. This is a subtle and loving art that may not be bought by anybody, it requires to be practice with care and constancy by the human being who undertakes the task of being companion to the formation of sustainable future co-creating subjects able aware of life.

A creative healthy relation is seen as stake with two ends, a "good" one and a "bad" one: the one that pretends to help would have to keep the "bad" end, so that the interlocutor would have easy access to the "good" end. One cannot demand to the other something that he cannot still do. It is impossible to teach the other to wish something for what would have to struggle.

The essential for the mutual construction of a grown path is the equanimous and persistent desire as the capacity to open spaces for the new, as when one perceives the freshness of a diaphanous awareness, as it is in an infant. The profusely informed intellect should learn to discriminate and get rid of excesses, without neglecting the feeling of gratitude to some intellectuals for leaving their trace. There are not definitive conclusions in this impressions reception movement, but is clear that having that "*to place intellect for being service*" is very different of "*to be an slave of the intellect*".

The partial way to address educational and learning processes has generated all kinds of deformations when trying to develop many of the fundamental qualities and dimensions of human beings and of life. For this is what we have

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<sup>19</sup>Kenny Werner, in his book *Effortless Mastery*, deals with this matter that is applicable to any human activity, as for example; cut logs with a sardine (Werner, 1990).

interest to address ignored issues when dealing with subject education.

The self-knowledge practice has the purpose to open our mind to the largest mysteries that occur at every moment allowing for an affectionate relation with environment that produces the impression of infinite space and time. This experience enriches our participation in the world converting our different activities in something pleasant—to say the less. By this practice there is not need to shelter in any specific teaching, our behavior may be consider as spiritual for simple and straightforward adherence to the most intimate interior experience.

A person with ample relational capacity is the one that experiences its own self, through a constant and careful transdisciplinary education, as a subject that transcends the apparent contradictory concepts of objectivity and subjectivity.

To the reintegration of the human being in the process of knowing and staying in the world, Basarab Nicolescu denominates as “transdisciplinary attitude”. From this attitude we affirm that the subject education requires of all that allows attending rigorously its *Self-knowledge* and *Care for the Quality of Being*, to this we denominate “*transdisciplinary education*”.

## 13.12 Conclusion

In this chapter we have recuperated the essential care towards the knowledge subject in a repeated and dedicated manner, as befits when it is acknowledge the central place in our knowledge for the human being. For Transdisciplinarity education, “to be or not to be” is a central matter and in this way to be depends on the relationship with oneself and from there with all that exists.

The possibility of education with transdisciplinarity methodology could give birth to a human being who will find his place between the infinitely small and the infinitely large, who is aware of the multiple interactions that may be established; a person that would empathically will relate with himself and the others, and will be able to go beyond the world view that rejects contradiction and uncertainty, but above all that serve lovingly his inner world. It is from this inner world care that we humans may rebuild a life and a knowledge that is respectful of other human beings and of our world.

The education with a transdisciplinary methodology seeks the co-creation of learning spaces that allow us to cultivate the proper relation subject to object so that the sacred and mysterious Hidden Third. For the actualization of this Hidden Third the cultivation of subtle and deep kind of attention is required. This aspect is neglected in the current systems of education.

We have emphasized that in order to obtain the attention quality required so as to include the emotions connected in the relation subject/object would required and effortless dedication. Through words and images that we have shared in this text we pay special attention to the largely absent in educational work, even within the current transdisciplinarity training and we have named

being-body. Given our ancestral duality form of seeing mind-body/subject-object, it is unavoidable to get back to a pure concepts and ideas world. That is why we have repeatedly indicated the need to re-embody the educational process from the living experience of the totality of our being-body.

I live between what is that I live now, Breath that connects me is a gift, When the look from my being opportunity gets involve, Then my world and the world open, Spread their wings, Wings that are relational threads weaving endlessly Blessed'm back to my presence in each exhalati...

This education with a transdisciplinarity methodology may mean a gift that as humanity we give to ourselves, as professionals and academics capable to build a tape of knowledge that will result in an ethical commitment towards life. Thus we will be able also to implement in vivo that will recuperate science as a deeply human activity and in touch with what Edgar Morin calls Real World.

The creativity of a transdisciplinarity educator will be able to appear in the active behavior of what corresponds to a true realization of the student towards his inner being and the necessary world knowledge, in order to diminish the gap between saying and doing, between being and knowing, between doing and taking care.

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**Antonio Gómez Yepes** born in Mexico DF on April 3, 1944. He has dedicated his entire life to the study and practice of Gurdjieff natural philosophy. He studied mechanical engineering and paint. He has worked in the development and manufacture of equipment; ship unloading, electronic scales and last 20 years manufacturing of electromagnetic therapeutic equipment. He founded and still manages a medicine clinic that uses a systemic approach developed by him, for treatment of autoimmune diseases and cancer He taught for two years (2011-2012) in the workshop of self knowledge at master's level in Veracruz University. He is currently participating in project development of International Masters program in Health, art and community of the Universidad Veracruzana.

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**Dr. Enrique Vargas Madrazo** is 50 years old. He was born in Mexico City, from a Mexican mother and Colombian father. He has three children, Paolo 25, Giuseppe 19, and Penélope 13 years old. His family lives in Coatepec, Veracruz, in the country side, very close to the beautiful river called Pixquiac. He studied biochemistry at La Habana, Cuba, and his master and Ph.D. degrees in Biomedical Research at the National University of Mexico. His present work is related to transdisciplinary re-learning process, transdisciplinarity and sustainability, deep ecology and simplicity, deep dialogue and community empowerment. At the present time his focus is to help his community, the EcoDialogue Station, to grow, to mature and expand towards new horizons.

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# CHAPTER 14

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## The Value of Transdisciplinary Collaboration in Robotics Education and Research

*Gerardo del Cerro Santamaría, Social Science at The Cooper Union for the Advancement of Science and Art in Manhattan, 41 Cooper Square, New York NY*

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*This chapter suggests that transdisciplinarity is rising as a powerful epistemic strategy for research in technology-related fields such as engineering. Though this topic has been approached from a philosophical perspective, we know little about the actual shape that transdisciplinarity might take in research and action. How is transdisciplinarity operationalized in research and professional practice? As a case study, we report an assessment study of communication modes and content used by engineering students in a special project-course, Robotics for Theater, focused on the planning and construction of a robot from scratch, to support theatrical production as actor and prop. Our assessment tools were based on ethnographic research and included questionnaires, journals, and students' expressions of their views on the communication and learning processes. Analysis of the case study of the Robotics for Theater project revealed that: 1. Resource mobilization was fostered by the role of the advisor as information facilitator and "weak tie" in the network, and also by the frequent informal contacts among the students in the team. 2. Innovation was fostered by intra-team trust. The strong friendship and teaming experience of the group were critical for effective team dynamics. 3. Probably due to time constraints, the field of theater did not become a fundamental reference of the project, contrary to plans. 4. Time constraints and technical difficulties in implementation inhibited progress. 5. Informal meetings were crucial in the progression of design and implementation.*

**Keywords:** Transdisciplinary collaboration, robotics education, ethnographic research.

## 14.1 Introduction

This chapter suggests that transdisciplinarity is rising as a powerful epistemic strategy for research in technology-related fields such as engineering. Though this topic has been approached from a philosophical perspective, we know little about the actual shape that transdisciplinarity might take in research and action. How is transdisciplinarity operationalized in research and professional practice? During the last decade, transdisciplinarity has become the focus of important theoretical contributions. More recently, innovative research strategies and methods tackling complex objects and contexts have been presented at academic conferences and seminars. One aim of this chapter is to present a case study of transdisciplinarity, which will not only improve our understanding of this approach but also illustrate how it can be operationalized in concrete ventures as it fleshes out our next technological futures. While architecture and planning seem to be fertile domains for transdisciplinary contributions (because of their very nature as multidisciplinary disciplines involving both the natural and social sciences, and action-oriented practices aimed at transforming the built and natural environment), little is known about the shaping of technological futures involving collaborations between engineers and social scientists. This chapter outlines a framework for transdisciplinary collaboration which is applied to the Robotics-for-Theater project, a transdisciplinary project made possible with NSF funding and developed at The Cooper Union for the Advancement of Science and Art in New York City.

This chapter presents the development and results of an assessment conducted on the Robotics-for-Theatre project, an educational initiative developed at the Cooper Union School of Engineering under the auspices of the Gateway Engineering Education Coalition of the National Science Foundation.

The purpose of the assessment was *summative*: we wanted to gather information about a team of students who developed a robot for theatrical performance in order to develop a protocol for assessment of similar future projects. In order to gather the information, a number of assessment instruments were designed and implemented. Students were asked to track ideas that were successfully applied to the robot, and ideas that were not. They were asked about the means of communication used during the development of the project. They were also asked to express their views on the learning process on a number of issues ranging from communication skills, to teamwork, to interdisciplinarity. The analysis of students' responses has allowed us to design a new assessment protocol.

Unlike the summative assessment performed, the proposed protocol is fundamentally *formative*: it has been designed to be a part of the overall design of engineering projects from the outset, and it specifies feedback loops for continuous improvement that should be implemented during the development of the projects. If successfully implemented, we believe the protocol can be an effective way to track and improve the learning by engineering students at Cooper

Union in a number of dimensions or learning outcomes. A successful implementation will require full collaboration among all parties involved in each project, especially faculty and students, the main players and beneficiaries of assessment practices.

This chapter is divided into six sections. Section 1 provides an overall background of the relevant literature and the research problem addressed here. Section 2 presents our case study, the Robotics-for-Theatre Project, in the context of the engineering curriculum at Cooper Union. Section 3, entitled “A Summative Assessment for the Robotics-for-Theatre Project” discusses the assumptions underlying the assessment plan designed and implemented. Section 4 is devoted to presenting the main results of our research, including a section on validity and reliability. Section 5 devoted to future work, presents our proposed assessment protocol for innovative, open-ended engineering projects. Section 6 summarizes the value of transdisciplinary collaboration.

## 14.2 Background

The explosion of information technologies during the past decade has revolutionized the practice of engineering, which, quite naturally, drives requirements for changes in engineering education (Siller, Palmquist, Zimmerman, 1998) [1]. Two key areas for change identified at the national level by industry, government and schools are 1) Teaming and 2) Design. The information technologies provide new tools for communication in the former and development in the latter. That is, distance learning, video conferencing, e-mail, and intranets provide a new medium for shrinking space and time in cooperative teams. Databases and CAD systems provide error-free archives and design baselines instantly accessible for the product.

The information technologies also provide a useful window into the team and design process for analysis and tuning of the teaching process. Educators can tap in to the stream of messages and designs, measuring the kinds of activities in progress, and find and correct problems in the curriculum. Larry Leifer pioneered such techniques, among others at Stanford University. Leifer electronically instrumented the communications streams between team members, analyzing their activities to assess the educational process and disseminate the results (Leifer, 1997) [2]. The original intent of his study was to develop methods to bridge the gap between professional practice and education with joint industry-academic product focused projects. An important discovery from this and other studies was that *team engineering is a critically social activity*. While any team effort of course requires social interaction, awareness and training of this aspect had been largely ignored in engineering education, which instead emphasized technical content.

The discovery of the importance of the social element led to deeper examinations of its nature via protocol analysis. Atman, Bursic, and Lozito (1996) [3] applied this technique to the verbalization of a student in a design project, coding sentences into categories which included Problem Definition, Informa-

tion Gathering, Generate Ideas, Analysis etc. Button and Dourish (1998) [4] discuss formally on the methods and application of protocol analysis in terms of *ethnomethodology*, i.e. treating engineering communication as utterances by an alien culture to be objectively analyzed by the anthropologist for the purpose of improving the culture (increasing engineering design productivity).

In an interesting study which focused entirely on the social interactions devoid of technical content, Bereton, Cannon, Mabogunje and Leifer (1997) [2] analyze the protocols of videotaped conversation in a design team, coding the results in terms of focus and transition. The former is a locking in of a design decision, which often requires assertion of authority based either on merit or power. For smooth teaming, this must be accompanied by persuasion, smoothing the feelings of the loser, and formal registration of the decision. Transition, on the other hand, requires cooperation, exposure of self to risk, and requests for help. The authors note that students are rarely trained in the use of such group dynamic techniques and manners. The authors of the paper at hand observe from their professional experience that the most successful team leaders in industry are superb at these social skills.

The work cited above describes studies which examine the communication associated with teaming and design. The purpose of the studies was to understand and improve skills in these two areas which industry deems of central importance, and hitherto neglected in engineering education. Our purpose is to learn from these examples, and apply communications assessment tools to the improvement of undergraduate engineering education. Every institution has unique characteristics, rendering universal methodologies inapplicable. Thus, we have selected and adapted some of the tools described above, and applied them to a pilot study. From the results of this study we propose a somewhat more general methodology for future courses, encouraging others to tailor their methods accordingly.

There are in fact a number of other programs operating on these premises. A good example is provided by the Cranfield University in UK's Decision Engineering Centre, which, as part of a study, provides an ICT (information and communications technology) based infrastructure to share data, information and knowledge for competitive industrial design. One of the goals of the study is to prove that by developing ontological representations of knowledge and using standard languages for knowledge-sharing, the design process becomes more efficient. The principle at work here borrows from some of the same studies that the Cooper Union regarded for its Robotics-for-Theatre assessment protocol, such as Leifer's push for an electronic communication stream and Button and Dourish's theory of protocol analysis.

More recently, a 2005 article in the Journal of Engineering Education entitled "Assessment in Engineering Education: Evolution, Approaches and Future Collaborations," describes conversational analysis, observation, and ethnographic studies as "promising techniques that have been rarely reported in engineering education."(Miller, Moskal and Olds, 2005) [5]. The promise of an ethnographic approach remains that it 'makes work visible' and highlights

the process of innovation. In the words of Ball and Ormerod, ethnographic assessments are appropriate to design because, “in design contexts... it is apparent that the goals of research tend to be more applied in nature, such as attempting to understand design *behaviors* in order to make design productivity more effective (e.g., through computer-based support or changes to existing organisational practices)” (Ball and Ormerod, 2000) [6].

Also in 2005, J.M Thom and M.A. Kimble-Thom conducted a widespread literature review and presented findings in their paper “Academic and Industrial Perspectives on Capstone Course Content and the Accompanying Metrics.” The literature review pertained to academic perspectives on engineering design capstones, and the authors also conducted interviews with members of industry and observed students participating in several design programs. Based on this research, the Thoms conclude that there is no dominant best practice for design course assessment. Like many others commenting on the situation, they recommend choosing protocol that best fits the school’s goals and resources. Whatever the protocol, they strongly encourage schools to be specific about desired student outcomes, which should be based on ABET standards, and the exact means by which students will be held accountable to these standards. The fear is that open-ended design projects lead to subjective grading. We believe The Cooper Union has done well to not only base course goals on ABET standards but also document which curriculum elements and assessment methods relate to which standard. The problem is that with qualitative measures, it is difficult to know what a sufficient response entails. For the purpose of converting qualitative measures into student grades, schools such as the Milwaukee School of Engineering address this problem with rubrics. Rubrics, however, are unnecessary to many of The Cooper Union’s assessment measures because the focus is on investigating the learning process rather than evaluating students. Objective student evaluation measures, of course, do still exist.

The Thoms highlight a recurrent problem in that many design course students appear to struggle with knowledge synthesis. They do not look past engineering for ideas, do not seek help until problems arise, and generally act according to a “knowledge garnering paradigm,” which excludes planning and foresight. The Cooper Union’s assessment protocol addresses these concerns by asking students to state explicitly what they learn from other disciplines as they work on the project and by providing regular consultation with faculty outside of a troubleshooting capacity, requiring students to outline and review changes in product conceptions, and allowing each member to serve as team leader. An example of the results obtainable by the school’s assessment protocol is provided by student responses to team profile and end-of-course questionnaires as well as faculty comments and observations from the pilot program.

## 14.3 Case Study

For a case study, we wished to assess the communication within a coherent team on a well-defined but creative project which challenged the team members and provided ample need for communication. The project should be a focused design with challenging technical requirements. Just prior to the start of our study, Professor Adrienne Wortzel, who has authored and directed theatrical productions involving robotics and live Web media at Cooper Union, Lehman College, and international venues, approached the department with a proposal for technical collaboration for robotics and theater. This resulted in a special project course, ME363, followed by ME364 and EID111, “Robotic Visions and Theater.” The case study was based on a design team of students who worked in all three of these courses, adapting and developing robotics platforms for theatrical performance.

### 14.3.1 Description of Project-Course

ME363 is a special topics course for upper classes with a firm technical background in Mechanical Engineering behind them. The project consisted of adapting the control system of one of Adrienne Wortzel’s robots, which had been remote control via radio link, to remote control from a computer program which triggered the radio link. This was to be the first step in a long-term goal to provide web control panels for robots, enabling theatrical directors and choreographers with the ability to control robots without having programming skills. The technical goals, while superficially simple, required programming, digital-analog circuit design, RF noise isolation, and driver level software. Gain tuning, impedance matching, and all the unwritten interference problems between digital and analog circuitry cropped up unexpectedly and had to be solved for a working demo. These problems challenged the students’ technical knowledge, problem solving skills, and ability to recruit help when beyond their experience (e.g. RF interference). Professors Weiman and Wortzel provided guidance for the course at the requirements level. Technical direction and week-to-week feedback was provided by Professor Wei and consultant Ericson Mar, a recent graduate and robotics expert. An assessment for the course was designed and implemented by Gerardo del Cerro, Director of Assessment and Professor at the Cooper Union School of Engineering.

The course met once a week for three hours, providing intense interpersonal communication and project work. Other components of labor were provided individually by students during the intervening days. A web site was used as a repository for design decisions, technical information, and journal entries narrating the design process. The end result of this project was a working demo successfully showing the integrated functioning of the components.

ME364 followed, using the same team (described in the next section). In this course, the knowledge learned by the team was applied to the design of a from-scratch robot, using the HandyBoard (68CH11 based) robot control

package from MIT. A body, displays, control system, and remote video were designed and built by the team. The user interface for the ME363 robot was based on key-commands from QBASIC. The ME364 interface was higher level, based on a Visual Basic form with command buttons for direction, speed and state. The architecture and interface were more advanced than the ME363 robot and required considerable digging for components, interfacing, and programming. Ericson Mar provided a crucial role in guidance towards resources and the www was a major source of information. The EID111 course only peripherally involved the team for ME364, but nevertheless provided a bridge and application context for the robot project.

### **14.3.2 Robotics Team Profile**

The robotics team consisted of three juniors and one senior, all ME majors. They had worked for at least two years together on courses and projects and were aware of each other's particular characteristics. The working profile of these students bears some discourse because of its impact on the methods of communication. All commuted to school from nearby neighborhoods, and did not live on campus. Most worked part-time, and did not use e-mail from home. Thus, their time at campus was scheduled, and significant communication was face-to-face, i.e. this was not a distance learning nor intranet experience.

The assessment plan for this project included a brief questionnaire designed to address these issues. By responding to the questionnaire, the team members gave us important information which can help *to track the external networks and therefore to uncover the dynamics of resource mobilization* which takes place during the development of innovative, open-ended projects such as the Robotics-for-Theatre. The Team Profile resulting from the responses of the team members to the questionnaire is included below.

### **14.3.3 The Cooper Union Context**

The publications cited in the Background and References sections describe studies conducted at large institutions with sufficient engineering populations for statistically representative results and sufficient resources to conduct in-depth analysis. Cooper Union, on the other hand, is a small institution and resources for this project were limited. Protocol analysis of videotapes and electronic metering of network communications were out of the question for this pilot study. The latter was not much of a loss; our compact campus and personal interactions between students diminish the need for distance learning. In fact, the size and quality of the school offer unique opportunities for efficiency and quick response. We encourage other universities to exploit their own unique characteristics in tuning their studies in engineering education assessment. Below we describe our characteristics.

Cooper Union has a nationally renowned School of Art, an internationally famous School of Architecture, and a top-flight undergraduate School of

**Table 14.1:** The Cooper Union at a glance

Cooper Union Enrollment Demographics	Women	African American & Latino-American, and Native American	Asian-American
Engineering	470	30%*	10%
Art	280	45%	16%
Architecture	155	43%	21%

\*Almost double the national average for schools of engineering.

Engineering. Our small size, culture of intellectual curiosity, and tradition of integrating research and practical experience with education provide an excellent backdrop for adapting exemplary educational materials in innovative ways.

Cooper Union offers bachelors degrees in art and architecture, and bachelors and masters degrees in engineering (see Table 14.1). Admitted on merit alone, all 900 students receive full-tuition scholarships. About 40% of our students were born outside the U.S., and a similar percentage needs financial aid beyond the full-tuition scholarships. For over 150 years, Cooper Union has been a means of social mobility for a multicultural, largely urban student population whose members are often first in their family to attend college.

The School of Engineering offers chemical, civil, electrical, and mechanical engineering degrees, plus a general engineering BS degree and studies in cross-disciplinary fields such as biomedical, environmental, materials, and manufacturing engineering. Teresa Dahlberg, one of the nation's first woman dean of engineering, leads the school's 31 full-time and 53 adjunct faculty. In 2013, *U.S. News & World Report* ranked the School of Engineering first among U.S. undergraduate engineering schools; and *Time Magazine/Princeton Review* ranks it as the nation's third most selective school, tied with West Point.

In fact, our robotics team consisted of three females and one male, from a variety of ethnic backgrounds.

## 14.4 A Summative Assessment for the Robotics-for-Theater Project

The objective of the assessment of this project was mainly *summative* and experimental. It was planned so that we could gather information about the work of the team at different levels. The purpose was to develop a protocol for assessment of similar projects in the future. Thus different methods for collecting information were developed and implemented, and the data analyzed (see below). The *formative* dimension of assessment was not stressed, although it is the thrust of the designed protocol for use in future projects. For instance,

the use of a website as an archive and bulletin board was new to this course, and was not used primarily as a source of development, but rather as a destination of reports. There were no means for intranet privacy, and students rarely used the site from off campus. Therefore, the situation was not appropriate for the kind of “electronic instrumentation” cited by Leifer (1997) [2].

Due to the experimental and summative nature of this pilot assessment, the assessment objectives were not explicitly formulated at the outset of the project, nor were they incorporated into the overall structure and development of the Robotics project. The assessment plan was designed and implemented by Gerardo del Cerro, Director of Assessment and Professor at the Cooper Union School of Engineering. The specification of objectives, the design of assessment instruments, the process of data collection and preliminary analysis took place during the Spring of 2011, and towards the end of the project. A second phase of the assessment developed during the Summer of 2011, and consisted of weekly meetings for discussion of results and design of the assessment protocol presented in this report. Profs. Chih-Shing Wei and Carl Weiman, and Consultant Ericson Mar, in the Mechanical Engineering Department, fully participated in this phase. Similarly, this report is the result of the collaboration among the four authors.

As an ethnographer and participant-observer, the work of the assessor developed in parallel to the work of the team, although for a relatively brief period of time. The assessor was present in the weekly working meetings of the team scheduled between February and April 2011. The assessor became familiar with the members of the project and with the general direction of their work. During this first phase of the assessment, the specific purpose was to document interactions among the various members of the team in order to meaningfully track the course, content, and types of information flows. Observation sessions were complemented with semi-structured, informal interviews and direct questions to the members of the team.

Ethnographic observation of the work of the team was indeed critical for a meaningful formulation of a situated assessment plan (Suchman, 1987) [7]. Nevertheless, the assessment results presented in this report do not constitute so much an assessor’s ethnography as *an ethnography by the team itself*, however guided by specific questions and however modest in purpose. Communication flows within innovating teams are hard to track by participant-observers unless the ethnography encompasses the full duration of the team project itself. Whenever possible, the ideal situation is to have the team members record such flows, as well as other pertinent information for assessment. We asked the team members of the Robotics-for-Theater project to do just that. Through individual self-assessment, the multiplicity of perspectives inherent to all collective endeavors is not distorted. The final questionnaire was prepared and administered to the team members after the completion of the project.

### 14.4.1 Assessment Principles

The assessment plan was formulated according to the following working assumptions:

- (a) **Learning is a network-like process**, not an individual gain in one's own stock of knowledge. Learning is then a purposive (there is a clear means-ends sequence), and context-bound exercise which consists of a) juxtaposition and interconnection of concepts and ideas relevant to the context of teamwork; b) diffusion of such concepts, ideas, and their interconnection; c) ability to communicate them, a prerequisite for a successful diffusion; d) ability to resolve potential conflicts among competing ideas or proposals.
- (b) **Team projects foster innovation.** The challenge of this project is to produce innovation by incorporating wider circles, emergent relations, and weak ties into an open-ended task with multiple solutions. Innovation is a function, among other things, of the number of ideas and concepts that get to be discussed. The wider the circle, and the more and more varied the sources of information, the more likely is innovation to be achieved. Unlike diffusion of information as it may proceed in intellectual circles, what we are dealing with is identification of sources of innovation in language and use of such sources in the design (learning) process. It's not so much diffusion of information from a core of experts, but rather the use of information (resource mobilization) by a group of innovators. The main indicator of innovation/creativity in team design contexts, based on a scientific study, is number of noun phrases (see Leifer, 1997, 1998) [2].
- (c) **Creativity, and the possibility of innovation (successful conceptual design), may be a function of:** a. **Size:** Number of sources of information; b. **Heterogeneity:** Variety of sources of innovation; c. **Density:** Close and intense face-to face interaction among participants may be extremely important for the success of the project; d. **Time:** internal and external constraints due to deadlines, commitments to clients, dependence on suppliers, dynamics of team interaction etc.; e. **Successful interaction** among team members, that is, effective application of skills such as consensus building, conflict resolution, assessment of alternatives etc.; f. **Ability of team to learn:** if we define learning as a network process (see (a), above), then the ability to learn is closely related to the ability to mobilize resources, adopt and adapt ideas, and to use information throughout all steps in the design process. The value of assessment lies upon the fact that learning may be facilitated by the implementation of feedback mechanisms based on collection and storage of relevant information produced during the development of the project.
- (d) **Gathering data about the members of the team helps to measure innovation and learning.** Data about the team members works

as a baseline, or initial point for comparison. A Team Profile may be an effective way to store such data. These data would provide us with important information on: a. the type of networks of the team members (occupation of family members, major of friends...); b. their educational background (class, GPA, and GPA major, robotics courses taken, design courses taken, formal communication skills courses taken, oral presentation training, written communication skills, concept-generation training, elective courses taken in college); c. their professional/industry experience in design; d. their sources of information for the project; e. their learning styles (via MBTI results).

- (e) **Task clarification and product definition are critical in conceptual design.** The specific needs of the client are not always clear. There may be a statement of the task by the client, which should be recorded and stored. However, divergences, clarifications, specifications, unanticipated problems should be expected, and are to be discussed -and resolved- through ongoing interaction. Therefore, another important piece of information that should be recorded periodically is a statement of the task and the product *as interpreted by each team member at different points during the development of the project*. Manipulation of the definition of a concept may influence a concept-creation process (Robie, 1991, p. 101f) [8]. And here we need to establish a typology of design steps. Robie (1991, p. 187) [8] suggests 4 steps: 1. task clarification; 2. conceptual design; 3. redesign; 4. detail design

It seems clear that the client will need to be brought in for discussion on task clarification. Thus, we strongly stress the need to pursue *maximization of contacts with the customer*. In the context of a project-course, the ideal scenario would involve industry partners as clients. Other possibilities include advisors and professors playing the role of "the client." In any case, the students should be aware of the "discursive" nature of open-ended design engineering projects, and should be prepared to collect, store, analyze, and react upon the information on *product definition via communication* which is typically generated during the development of an innovative project.

- (f) **Analysis of team dynamics.** Despite of individual info-storage, face-to-face interactions, team dynamics and performance are worthy of assessment. Taping some of the sessions would be recommended. Ethnography, content analysis (with an appropriate software), conversational analysis, ethnomethodology are ways to analyze the information. Additionally, records of statements by each member of the team summarizing weekly team dynamics would help the goal of student self-assessment. Some guidelines for such statements could be: a. List main topics of discussion throughout the project; b. Identify the main discrepancies that occurred, the actors involved, and the mode in which were resolved; c. Identify the alternatives brought in for discussion and how one was

**Table 14.2:** The Robotics-for-Theatre project and the broader industry context

ROBOTICS NET-TEAM	<p style="text-align: center;">ABET CRITERIA (a-k): The engineering student as an emerging professional</p>	THE HORIZONTAL CORPORATION (from Castells, 1996)
<p>.Flexibility .Coordination: avoiding articulation errors .Feedback: corrective actions, in-time learning .Resource mobilization: spin-offs and close contact with core .Trust</p>		<p>.Process .Flat hierarchy .Teamwork .Assessment .Rewards based on performance .Maximization of contacts with suppliers and clients .Information training and retraining of employees at all levels</p>

selected.

- (g) **Measuring motivation.** Knowledge, experience and motivation seem to have an effect on team performance. A way of measuring motivation would be by asking the team members: a. to list fields of interest for future employment; b. to rate 8 design tasks (from Robie, 1991) [8]; c. to write a statement on initial motivation and expectations for the project.
- (h) **The current process of socio-economic and educational restructuring features a clear convergence of work methods, processes and objectives among R & D settings, industry and academia.** ABET is aware of this trend, and schools, Cooper Union included, are making efforts to cope with the changing socio-economic reality (see Table 14.2). Schools of engineering educate students who for the most part will work in corporate environments. In addition, schools are socially embedded institutions, and have an obligation to remain open to contemporary trends in order to fulfill their mission. We believe that projects such as Robotics-for-Theater contribute to this endeavor.

#### 14.4.2 Assessment Results: Tracking and Measuring Team Progress

As mentioned earlier, ethnographic observation of the work of the team was indeed critical for a meaningful formulation of a situated assessment plan (Suchman, 1987) [7]. Communication flows within innovative teams are hard to track by participant-observers unless the ethnography encompasses the full duration of the team project itself. Whenever possible, the ideal situation is to have the team members record such flows, as well as other pertinent information for assessment. We asked the team members of the Robotics-for-Theater project to do just that. Through individual self-assessment, the multiplic-

ity of perspectives inherent to all collective endeavors is not distorted. The assessment results presented below do not constitute so much an assessor's ethnography *as an ethnography by the team itself*, however guided by specific questions and however modest in purpose.

### **Main findings:**

1. Resource mobilization was fostered by the role of the advisor as information facilitator and “weak tie” in the network, and also by the frequent informal contacts among the students in the team. Resource mobilization was inhibited by intra-team trust and friendship, and by time constraints affecting the development of the project.
2. Innovation was fostered by intra-team trust, advising, and informal meetings. It was inhibited by technical difficulties encountered along the way, and by time constraints.
3. Interaction with client shows gaps along the way. Probably due to time constraints, the field of theatre did not become a fundamental reference of the project, unlike it had been planned. Students seem not to have learned much from or about theater.
4. Team dynamics was effective, although on occasion the division of labor separated the team excessively. Frequent informal meetings and contacts, the time-intensive nature of the project, and the trust ensured by friendship among the students helped teamwork.
5. Intensive intra-team communication via informal meetings made a difference in an innovative, time-intensive project like the Robotics-for-Theater.

The course of the student's product development was ripe with many opportunities to observe various forms of interaction. The client-based product development strategy of education involves many aspects of teamwork and design methods. This approach is similar to Stanford University's established principle for assessing engineering education called Product Based Learning, “a problem oriented, project organized learning activity that produces a product for an outsider” (Leifer, 1997) [2]. The observations were analyzed to produce useful conclusions on the communication modes leading to the formulation of the protocol.

**Resource mobilization for creative problem-solving.** As mentioned earlier, one of the major changes in engineering practice is the widespread adoption information technology. The internet has offered product development engineers increased productivity through a global knowledge base and asynchronous communications capabilities. As Brudiansky well put it, “the entire focus is on collaboration, exchanging ideas freely, and thoroughly documenting and presenting results” (Brudiansky, 1999) [9]. And the web constantly

plays a major role in Stanford University's Product Based Learning Programs (Leifer, 1997) [2].

One of the roles of the advisor was to expose the students to the wealth of information on the internet pertaining to robotics and introduce the concept of interaction with professional topic groups on the internet. Students frequented the Handy Board web site for info and tips pertaining to the design of their robot as well as information on the Handy Board itself. They searched the archives for user contributed source code that they could modify and reuse. They were able to ftp and use the latest versions of the relevant manuals, schematics etc. Also, a major advantage stemmed from the use of the Handy Board e-mail forum, where many questions were answered and tips were attained. As mentioned in the student surveys, ideas and social interaction from these external sources helped the project along.

Traditional methods of design were not neglected. Many catalogs and product specification sources were given for the students to use. However, this provision countered the internet-based learning objective in one student. It was mentioned in one survey that web searches for parts were fruitless compared to catalog-based searches. What didn't the student realize was the fact that the good majority of the catalogs were accumulated through internet searches in a past project. Perhaps in the future this can be remedied by indicating the origins or steps that led to the obtaining of the material and providing more unique opportunities to include internet searches as part of the development.

**Innovation and creativity.** A feature of American education is its strong focus on innovation. It is believed that this has provided the American technologists with the willingness to take the risks necessary to create new industries based on technology (Grose, 1999) [10]. To encourage creativity, projects are often open-ended like those found in Miami University's Design and Manufacturing Laboratory (Moller. et. al. 1999) [11] where students develop different approaches so solve a particular problem.

During the Robotics for Theater Project, the students went through periods of brainstorming and collaboration to design the product for their client. This produced many ideas to analyze and choose from. Through this approach, similar to the efforts of Leifer, the student's created a "product that embodies their knowledge" and used hands-on experience that "fused theory and practice" (Leifer, 1997) [2]. It was found that the advisor played a key role in providing the technical guidance that helped lead them to more robust designs. Though the advisor was careful not to produce solutions for the students, an action which would counter the original efforts.

The randomness and spontaneity of the solution formation coupled with the frequent informal interaction by the students produced a difficult scenario for tacking the origins of particular solutions. Post-assessment of the design yielded ambiguous paths from beginning to concept to manufacture. It is suggested that periodic logs of design decisions would help remedy this problem.

**Interdisciplinarity.** The chosen robotics project, being of a mechatronic nature, provided an opportunity for the students to experience the interdisciplinary nature of engineering projects. This case also included a non-technical influence, which was the client. As in real-world engineering projects, the product is often for a non-technical application. Associated with this is the need to interact across disciplines: both technical and non-technical.

The methods used for interdisciplinary interaction were internet-based and person-to-person communication. A significant contributor to the success of the project was through the use of the web, not only for reference as mentioned previously, but also for tapping into the various human resources in the world. Students were able to consult with professors, professionals, robotics hobbyists, and other students of various skill-sets, experience and field specialties who frequent the Handy Board email list. Personal interaction with an interdisciplinary mix of professor and students were critical in filling in the gaps throughout the mechatronic design. The advisor also served as an interdisciplinary source of information. One drawback experienced was the small amount of client interaction apparent throughout the course of the project. For the future, client interaction should be stressed more to ensure that the student's recognize the importance of meeting the needs from a non-engineering point of view.

**Teamwork.** The strategies for guiding teamwork included the encouragement of the division of tasks and the formulation of concurrent engineering practices. These principles are the foundation of modern engineering practices in industry and as Yazdani et. al. indicate, the trend is continually toward these ideals, where sequential engineering is being replaced by various forms of refined concurrent engineering (Yazdani et. al., 1999) [12].

Though during formal meetings, much of team interaction consisted of brainstorming and collaboration, a significant portion of teamwork occurred outside of the meetings. It was indicated repeatedly in the surveys that this informal discourse was a major contributor to the success of the project. Similar findings on product development courses are supported by Leifer, who wrote, "a significant portion of teamwork occurs in parallel, outside of meeting rooms" (Leifer, 1997) [2].

Teamwork helped distribute the load of work as well as harness the various individual skills of each member. Some of the students possessed the manual talent required for the actual construction the robot's mechanical parts. Another had the software and computer hardware skills that helped the team incorporate the computer and Handy Board in the design. And another had internet technology knowledge. All worked in parallel, performing their own tasks. This division, however, tended to separate the team members leading each party to be delved in his/her own aspect of the project. Neither party was familiar with each other's work. This resulted in communication problems when the individual accomplishments were ultimately joined to form the whole robot. It should be emphasized that product success requires the continual

communication of achievements and knowledge gained between members of the team.

**Communication.** A main objective of any project development course is to provide "opportunities to develop enhanced oral and written communication skills, learning contexts that provide experience working in teams, and increased use of design projects throughout the curriculum", characteristics which conform to the three most emphasized areas of the ABET 2000 theme (Siller, et. al., 1998) [1]. Participation in internet email forums was integrated into the project to develop written communication skills. Informal meetings were encouraged to enable interpersonal communications and relations. Meetings were held to enable interaction with the advisor along various topics of robotics engineering.

With the use of the internet, the students had opportunities to learn (through practice) written communication skills for web interaction with other interdisciplinary and multi-cultural students, professors and professionals in robotics. The asynchrony of email forces students to learn how to get the point through in an efficient and effective manner since there is no room for ambiguity. Ambiguity may delay response time and in the worse case, may not trigger a response at all. Siller et. al. support these notions in his literature (Siller et. al, 1998) [1].

Repeatedly mentioned in the surveys was that formal and informal meetings contributed a major part to the accomplishments of the project. Formal meetings enabled the organization and preparation of question and answer sessions through personal contact. Visual as well as verbal methods were used to disseminate information. Sketches were used to facilitate visually descriptive communication. Similar circumstances were evident in informal meetings as well.

Though, assessment difficulties stem from the informal interaction prevalent especially since this was the communication most frequently used. No method was established to track the informal gatherings of group members. These gatherings were often random occurrences that sprung from the need to address immediate unforeseen issues. Team members also interacted with external persons including those through the internet. Perhaps, in future projects, the students periodic logging of project activities would record these interactions.

## **14.5 Evaluation, Validity and Reliability**

Based on our own findings, we determined to analyze the validity and reliability of the results and the extent to which they are useful to the school's assessment purposes. While it is generally easier to examine the reliability and validity of quantitative measures, it is still possible to analyze qualitative results in this way, based on the suggestions of Guba and Lincoln (1981) [13] and other experts in social research methodology.

Generalizability is applied by researchers in an academic setting. It can be defined as the extension of research findings and conclusions from a study conducted on a sample population to the population at large. While the dependability of this extension is not absolute, it is statistically probable. Because sound generalizability requires data on large populations, quantitative research – experimental for instance – provides the best foundation for producing broad generalizability. The larger the sample population, the more one can generalize the results. For example, a comprehensive study of the role computers play in the writing process might reveal that it is statistically probable that students who do most of their composing on a computer will move chunks of text around more than students who do not compose on a computer.

Transferability is applied by the *readers* of research. Although generalizability usually applies only to certain types of quantitative methods, transferability can apply in varying degrees to most types of research. Unlike generalizability, transferability does not involve broad claims, but invites readers of research to make connections between elements of a study and their own experience. For instance, teachers at the high school level might selectively apply to their own classrooms results from a study demonstrating that heuristic writing exercises help students at the college level.

Generalizability and transferability are important elements of any research methodology, but they are not mutually exclusive: generalizability, to varying degrees, rests on the transferability of research findings. It is important for researchers to understand the implications of these twin aspects of research before designing a study. Researchers who intend to make a generalizable claim must carefully examine the variables involved in the study. Among these are the sample of the population used and the mechanisms behind formulating a causal model. Furthermore, if researchers desire to make the results of their study transferable to another context, they must keep a detailed account of the environment surrounding their research, and include a rich description of that environment in their final report. Armed with the knowledge that the sample population was large and varied, as well as with detailed information about the study itself, readers of research can more confidently generalize and transfer the findings to other situations.

**Credibility** is a measure of how much trust can be placed in responses provided by students and faculty through questionnaires and interviews. High credibility is inherent in the school's assessment methods of team member profiling, group observation, and faculty assessment, but there is potential for low credibility of responses on peer teamwork assessments and the end-of-course questionnaire. While peer assessment of team dynamics is essential, such a measure is always in danger of low credibility because differences in student perceptions and motives could lead to disparities that are difficult for faculty to rectify. In The Cooper Union's case, however, faculty/team interaction was so frequent that faculty did have a good working idea of team dynamics. Furthermore, since peer teamwork assessments were not used for

grading, there was little motivation to skew responses. In the future, the school can maintain the credibility of peer teamwork assessments by continuing a high level of faculty/team interaction and by establishing a vocabulary so that students apply the same standards to each other. In regards to the end-of-course questionnaire, the specificity of most of the questions serves to reduce aberrant interpretations and forces students to support answers with concrete examples. As with peer teamwork assessments, constant interaction with the team allowed faculty to anticipate and validate responses to most of these questions. In the future, reliance on web-based portfolios will allow for more frequent feedback and validation of student reports by faculty, thus creating more credibility.

In a similar vein, **Confirmability** refers to the extent to which assessment results can be corroborated by others. The school's pilot report is sufficiently confirmable, as the report errs on the side of quoting large portions of student and faculty responses. The point of the lengthy quotations is to establish the full context of the pilot for the purposes of ethnographic study. The result is that little data is filtered, so it is easy for third parties to understand how the school derives its conclusions and to appreciate that plenty of material is available in its original format. The measures with the lowest inherent confirmability are interviews and direct observation, though transcription and videotaping go a long way in addressing these problems.

**Rigor** refers to the complexity or sophistication of the assessment methodologies, thereby reflecting the quality of results. Sufficiently rigorous assessment measures require faculty to demonstrate that measures are based on intensive planning and that they are capable of handling qualitative results and applying them in a course. In regards to the Robotics-for-Theatre pilot, assessment measures appear to have been well-planned. It is clear from several tables included in the report that certain ABET standards were targeted prior to the creation of the course, and the report's outline of assessment principles reveals how the protocol is based on theory. Where the report lacks rigor is that not much is said about how faculty are supposed to analyze results and relate them to course goals. There is no mention of rubrics or a final grading structure. Still, this is an area where The Cooper Union is allowed to deviate from other schools because of its resources. The detailed analysis provided by Dr. del Cerro in the pilot report proves sufficiently that the few responsible for assessment of these courses have well-defined notions of what students ought to demonstrate. A process that would be too time-consuming and idiosyncratic to pull off at other schools fits well into The Cooper Union's intimate environment. Standards may need to be more clearly defined if the program is expanded.

**Transferability** refers to the extent to which similar results would occur in different settings. Transferability is related to the measure of dependability (the extent to which results are repeatable in a common setting), as assessment

results should be guaranteed dependable before they are compared to other contexts. This is problematic for the school since the pilot report only includes assessment results from one study. In order to ensure that the assessment protocol is transferable (and credible), it would be beneficial to conduct additional pilots and/or to compare pilot results with the results of subsequent design course assessments. It is also possible to gauge the dependability of the school's assessment results by comparison to results of similar studies at other schools, particularly if the students and schools have similar characteristics, but such comparisons are difficult to make on qualitative measures, as each school has its own priorities and phrasings. In this case, the most important component of transferability is **applicability**, or the extent to which results can be used to affect future courses through curriculum restructuring. In other words, do assessment results help the school make the course better? According to The Foundation Coalition, successful assessment schemes require three components: "a statement of educational goals, multiple measures of achievement of the goals, and use of the resulting information to improve the educational process." The University of Detroit Mercy's process of applying assessment results to course structure is similar to that of The Cooper Union. During a pilot design course at Detroit Mercy, instructors found through student surveys and in-class observation that uncertainty on behalf of students as to what was expected of them in assignments and projects was holding up the learning process. In response, the school created checklists to be used for presentations with more detailed criteria. Because of the overall assessment protocol's high internal utility, it is likely that a similar protocol could be applied to courses in other departments at the school. Capstone and cornerstone courses are common in a variety of disciplines, including architecture, art, communications, and business, and that the use of electronic portfolios is increasingly popular in design fields. Emphasis on teamwork, innovation, and design is appropriate for any of these fields; the difference would come in the structuring of outcome goals. Because the limited information available about design courses in these fields is applicable to The Cooper Union environment, pilot studies are the best recommendation.

Changes in the engineering education paradigm mean there are no hard and fast answers to the question of how to evaluate students. Each method has its merits and problems, but it is commonly repeated that the ideal depends on the school. Nonetheless, there is sufficient proof that formative, qualitative, and web-based assessments are normal features of the Higher Ed landscape. The main drawback to these styles is that they require time and patience, but at the Cooper Union, it seems appropriate to have an assessment model that takes advantage of the school's intimate environment, in which faculty members are able to interact and monitor students much more carefully than they could at other schools. It is possible to streamline the assessment process through quantified measures, but some information will be lost. As long as faculty members involved in the program continue to feel that student learning in the design course outweighs the costs of administering the current assessment

protocol there is no compelling reason to make major changes, especially since minor adjustments are inherent in the system.

## 14.6 The Proposed Protocol

The student projects studied in the pilot program assumed the format of client-based product development and delivery. A preferred scenario would involve industrial partners who sponsor and participate in specific product prototyping projects. In this ideal case, a technical representative of each industrial partner would be the *client* to the student team working on the industrial partner's project. This model has been successfully implemented by Prof. Leifer at Stanford University, through a graduate-level project course (Leifer, 1997) [2]. Building such an industrial alliance is an ongoing effort of the Department. For the pilot program, an emulated setting was adopted during the 2011-2012 academic year in which the instructors or advisors of these student projects also play the role of the *client*.

The ways and means for transporting information among members of a product development team and its client have a major impact on the outcome of the development effort. An objective of the proposed pilot program is to analyze this transport of information for the purpose of assessing and enhancing the students learning experience. A set of communications protocol will be implemented to enable better understanding of the information flow among students engaged in a common engineering design and manufacture project. Two key elements of this proposed protocol are Web-based archiving of communications among the students and instructors, and videotaping of selected student team discussion sessions.

## 14.7 Future Work

The proposed communications protocol will address the following issues:

1. **Resource mobilization for creative problem solving.** A Web-based team portfolio will be established to track the progress of each student project. It will feature a Product Definition section where definition and specification of the product, formulated by the student designers and their client, are recorded. It will also feature a Resource Mobilization section for periodic gathering and analysis of how students access and utilize information for creative problem solving. The sources of information, as well as their relevance to the problem solving process, will be recorded. A timeline for the resource mobilization process will be maintained to facilitate the students' own evaluation of how timing of discovery of information propels the flow of the problem solving process. The client of the product development effort will monitor this archive of resource mobilization, and provide feedback to the student designers to either reaffirm or redirect the flow of information.

2. **Innovation and creativity.** The team portfolio will feature a Project Profile section where information utilization and student initiatives are recorded. This provision will facilitate the instructor's assessment of the students' use of technology, as well as their general problem solving skills. Each student designer is expected to demonstrate his or her abilities to design as well as to analyze and interpret data, to identify, formulate, and solve engineering problems, and to design a system, component, or process to meet desired needs. In addition, emphasis will be placed on assessment of the students' understanding of professional and ethical responsibility, and the need for life-long learning.
3. **Interdisciplinary requirements.** The team portfolio will feature an Interdisciplinary Elements section to highlight the interdisciplinary characteristics of the project. Recruitment of students from non-mechanical engineering disciplines to participate in the student projects will be a priority during the initial team formation. Students will be encouraged to identify specific elements of the product development process that they perceive to be interdisciplinary.
4. **Teamwork.** The team portfolio will feature a Teamwork section to track the birth and growth of team design concepts, product components and modules, and general interactions among the student designers. Video-taping of selected student meetings will be used to aid in the assessment of the students' teamwork competencies such as conflict resolution, consensus achievement, effective oral communications, and leadership. Each student will assess the other team members.
5. **Communications.** A Communications section will be featured in the team portfolio to provide a depository for student communications and feedback, minutes of meetings, and student presentations. Monthly review/assessment meetings will be held to identify blockage points of information flow, and to continuously improve the communication channels affecting the advancement of the product development process.
6. **Management/Leadership.** Each member of the team will rotate as a leader of the group, and will have periodic responsibility for managing the development of the project. The team leader will be responsible for periodically reviewing the ongoing assessment data and will give feedback to the group.

## 14.8 Conclusion: The Value of Transdisciplinary Collaboration

Transdisciplinarity connotes a research strategy that crosses many disciplinary boundaries to create a holistic approach. It applies to research efforts focused on problems that cross the boundaries of two or more disciplines, such as research on effective information systems for biomedical research, and can refer

to concepts or methods that were originally developed by one discipline, but are now used by several others, such as ethnography, a field research method originally developed in anthropology but now widely used by other disciplines.

When the very nature of a problem is under dispute, transdisciplinarity can help determine the most relevant problems and research questions involved. A first type of question concerns the cause of the present problems and their future development (system knowledge). Another concerns which values and norms can be used to form goals of the problem-solving process (target knowledge). A third relates to how a problematic situation can be transformed and improved (transformation knowledge). Transdisciplinarity requires adequate addressing of the complexity of problems and the diversity of perceptions of them, that abstract and case-specific knowledge are linked, and that practices promote the common good.

Transdisciplinarity arises when participating experts interact in an open discussion and dialogue, giving equal weight to each perspective and relating them to each other. This is difficult because of the overwhelming amount of information involved, and because of incommensurability of specialized languages in each field of expertise. To excel under these conditions, researchers need not only in-depth knowledge and know-how of the disciplines involved, but skills in moderation, mediation, association and transfer.

The research presented here as a case study represents one example of the necessary collaboration between social scientists and engineers, a collaboration illustrating the value of transdisciplinarity in technological futures. A critical defining characteristic of transdisciplinary research is the inclusion of stakeholders in defining research objectives and strategies in order to better incorporate the diffusion of learning produced by the research. Collaboration between stakeholders – social scientists and engineers in our case – is essential, not merely at an academic or disciplinary collaboration level, but through active collaboration with people affected by the research and community-based stakeholders. In such a way, transdisciplinary collaboration becomes uniquely capable of engaging with different ways of knowing the world, generating new knowledge, and helping stakeholders understand and incorporate the results or lessons learned by the research.

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# CHAPTER **15**

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## **Transdisciplinary Science Methodology as a Necessary Condition in Research and Education**

**Orhan Güvenen**, *Bilkent University, Professor of Strategic Decision Systems and Econometrics, Ankara, Turkey*

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**T**raditional methods are not sufficient to deal with highly complex questions of modern world. Transdisciplinarity is mandatory to understand and solve those problems, which exist within the domain of multiple disciplines. Subsets' optimal does not always equal to the optimal of the general system set structure. Transdisciplinary approach is mainly focuses on a process of synthesis and aims to reach set optimal. The amount of data produced and distributed through modern communication channels is huge and remarkable percentage of this data is not genuine. That leads to a phenomena which is called information distortion. To minimize information distortion and maximize information security principles of hermeneutics must be embraced. A transdisciplinary approach in education is required to educate future generations to deal with complex problems of the world. The dominant system of the world is System 2, which is driven by power and money. The dominance of System 2 causes serious problems at world level like conflicts, wars, human traffic, drug traffic and degradation of natural resources use. To prevent such problems and to solve the existing ones System 1, which is based on science, technology, innovation and uses ethics as a constant, should be embraced as the dominant world system.

**Keywords:** A-STEM-H, transdisciplinary domain, trans-sector, transdisciplinary curriculum.

## 15.1 Introduction

The scope of science and its structure is constantly changing and evolving. As the science progresses over the time, it has to deal with more complicated issues and manage to come up with minimum error margin to scientific explanations and solutions. Due to the iterative and evolutionary nature of science, in time dynamics, more complex ones emerge. Most of the complex scientific issues exist in the domain of multi scientific disciplines.

To deal with sophisticated questions with high degree of complexity, requires the cooperation of multiple scientific disciplines. It needs to be targeted to the problem, analyse, interpret, converge to solutions with an iterative transdisciplinary approach which endogenize various disciplines.

The complex scientific issues that deals with multiple disciplines used in general the following approaches:

- Intradisciplinary Science Methodology
- Interdisciplinary Science Methodology
- Multidisciplinary Science Methodology
- Transdisciplinary Science Methodology

*Intradisciplinary Science Methodology:* Science methodology which concentrates on research and education systems within the same scientific discipline.

*Interdisciplinary Science Methodology:* Researchers interact with the goal of transferring knowledge from one discipline to another. Allows researchers to inform each other's work and compare individual findings.

*Multidisciplinary (Pluridisciplinary) Science Methodology:* Researchers from a variety of disciplines work together at some point during a project, but have separate questions, separate conclusions, and disseminate in different journals. It is dominantly a synthesis approach.

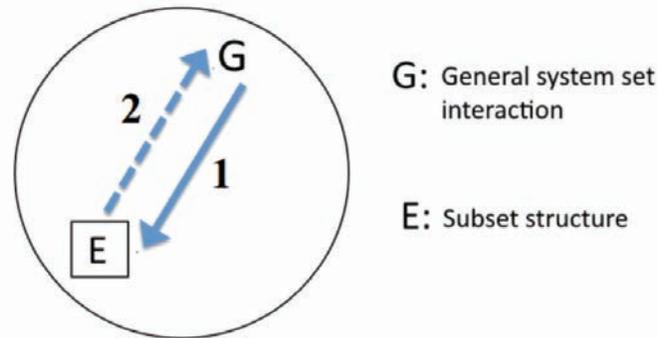
*Transdisciplinary Science Methodology:* It can be defined by following points:

- Being targeted to complex phenomena
- Working in an iterative approach
- Continuous cooperation of various sciences and disciplines converging to the solution of determined problem.

Figure 15.1 [1] shows the interactions between set structure and subset structures. As it is well known, the sum of the subsets' optimal is not equal to the set optimal. This theorem can be summarized with the formula below:

$$\sum \text{subset' optimal} \neq \text{Set Optimal}$$

In the light of the information provided by the theorem it is possible to estimate that both approaches, interdisciplinarity and multidisciplinary



**Figure 15.1:** General system set interaction and subset structure (Güvenen, 2000).

(pluridisciplinarity), leads to solutions which are under optimal and cannot use the full potential of the scientific disciplines which are used in research and education. To converge to the optimal solution, the transdisciplinary science methodology can be considered as a necessary condition.

In Arise 2 report by American Academy of Arts and Sciences there is an important observation which is : “Efforts to take advantage of these opportunities, however, have met significant barriers. The current organization of the research sector complicates communication and collaboration across disciplines. Furthermore, fundamental advances are not being translated efficiently into new products and services.” [2] This observation clearly states that lack of proper communication and low level cooperation between different sciences and disciplines causes serious problems to converge to optimal solutions. Joseph E. Brenner describes transdisciplinarity as being supported by three major conceptual “pillars” which are complexity, levels of reality and logic of the included middle or third [3]. He asserts that the general methodology of the transdisciplinarity is based on those three conceptual pillars and the roots of those pillars lie within the domain of modern science.

## 15.2 Transdisciplinary Science Methodology, Information Systems, Big Data and Information Distortion Interactions

As it has been previously mentioned above both interdisciplinary and pluridisciplinary methodologies obtain general scientific data from each discipline as the first step in research. They combine the obtained data, make a synthesis and come up with a final result. The limited interaction of these approaches causes under optimal result; because the sum of subsets’ optima usually isn’t

equal into being set optimal. Interdisciplinary and multidisciplinary (pluridisciplinary) approach focus on the subset and partial analysis which lead to quasi systematic and under optimal end solutions in social sciences because of not comprehending the properties of social phenomena.

There are three main structural properties of social phenomena. These are:

- Mathematical complexity
- Mathematical chaos
- Low predictability

To understand the true nature and essence of systems that social sciences deal with, it is important to consider all these factors together.

It is important to develop an exterior point of view to see the set structure and create an optimal solution in the light of the factors mentioned above. It is not possible to solve a problem of a specific discipline by using only the data and methods of that scientific discipline. Input from various other scientific disciplines and contribution of scientists with different sets of skills are required to come up with an optimal solution.

Transdisciplinary research includes the key components of interdisciplinarity, along with the incorporation of external nonacademic knowledge, applied to solve practical problems. Transdisciplinary research leads to a creation of new paradigms and provides pathways to new frontiers. Atilla Ertas states that transdisciplinary research includes key components of interdisciplinarity with the support of non-academic knowledge which forms an application to solve practical problems; thus transdisciplinary research changes paradigms and forms new frontiers [4].

The structures involved with science, society and especially individual are known for being mathematically complex, chaotic and low predictability. If we consider these structures as functions of “n” variables tends to the infinity. A change in one or few variables, can cause serious changes in end results.

One of the most important contemporary key concept in modern world is called big data. Big data is a term which is used to describe the exponential growth and availability of data in both structured and unstructured ways. Big data maybe as important to business and to the society, as much as Internet has become [5].

Big data creates an extreme volume of data. 100 terabytes of data are uploaded daily to Facebook; Akamai analyses 75 million events a day to target online ads; Walmart handles 1 million customer transactions every single hour. 90% of all data ever created was generated in the past 2 years. "90% of data generated is 'unstructured', coming in all shapes and forms- from geo-spatial data, to tweets which can be analyzed for content and sentiment, to visual data such as photos and videos" [6].

In recent research by The Academy of Transdisciplinary Learning & Advanced Studies, information has been defined as: “conjunction of the energetic

processes involved in the transmission and reception of meaning and that meaning, such that information cannot be separated from the underlying physical processes of its generation" [7]. The article concludes that information is something that lies within, between and beyond all disciplines, which carries strong similarities with Brenner's transdisciplinarity description mentioned in the earlier parts of this article.

As it can be seen from the information provided above, big data opens a new era for social sciences by providing a huge amount of cumulative data as never seen before. However the increase in quantity of the information available to access does not automatically guarantee the increase in quality and authenticity of the information. While some of these information are genuine, some of them might be wrong or simply affected by a phenomena called "information distortion".

It can be safely mentioned that the information can be distorted, manipulated, distracted or influenced in order to mislead the user of the information for a specific purpose. There are various examples to these phenomena from all disciplines which all of them created very high social and economic alternative costs which are:

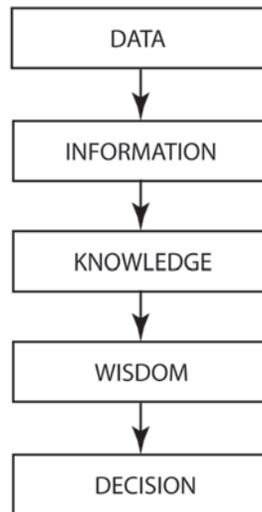
- Distortion of probabilities and outcome information in the direction of preferred decision alternative
- Information distortion can occur where the number of distinct pieces of information on the network increases

"Hermeneutics" is a fundamental rule in science methodology. The initial source, the initial signals may avoid in the time and space dynamics, high negative impacts and alternative costs that may occur [8].

Figure 15.2 [9] represents the path data takes and nodes it passes while transforming into the decision in the end. It clearly shows that distortion at any part of the linkage will affect the end result, in this case decision, in a negative manner. So it is really vital to start with reliable and distortion free data to come up with right decisions by using value added decision analysis and transdisciplinary science methodology.

Mathematical complexity and chaos models can be examined within the scope of non-linear mathematic. Error margins and information distortion in complex and chaotic systems cause serious problems for science and application areas. Due to that reason, the use of specific analysis and evaluation methods, which decreases the error margins and information distortion, increases the quality of the research and strength of the decision system. Figure 15.3 [10] illustrates the importance of transdisciplinary science methodology in minimizing error margins and information distortion.

"Information pollution" is an important challenge as environmental pollution, and it has to be considered and resolved sensibly.



*Figure 15.2:* The linkage between data and decision (Güvenen, 2014).

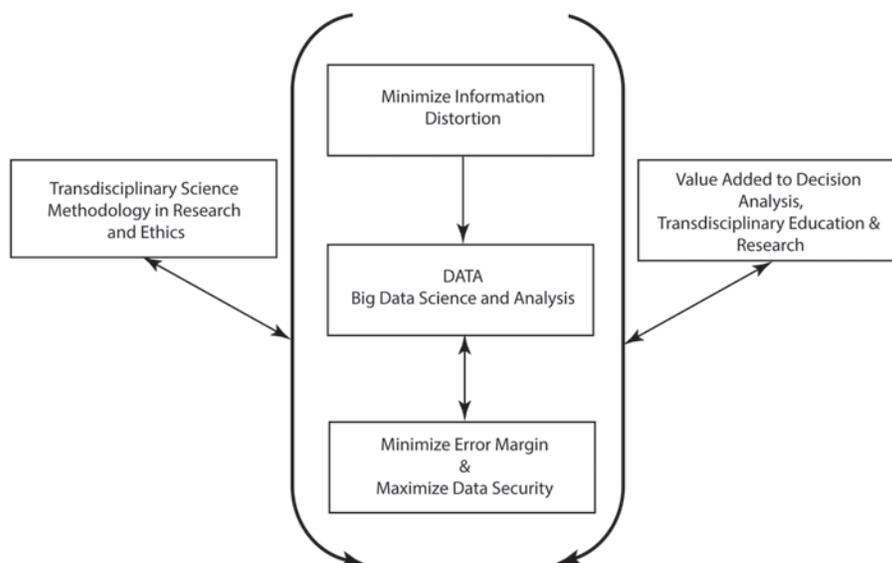
### 15.3 Anticipative Analysis and Transdisciplinary Science Methodology

Anticipative analysis is endogenous to transdisciplinary science methodology, especially in highly complex structures of social sciences would converge the decision systems to optimality and minimize alternative costs.

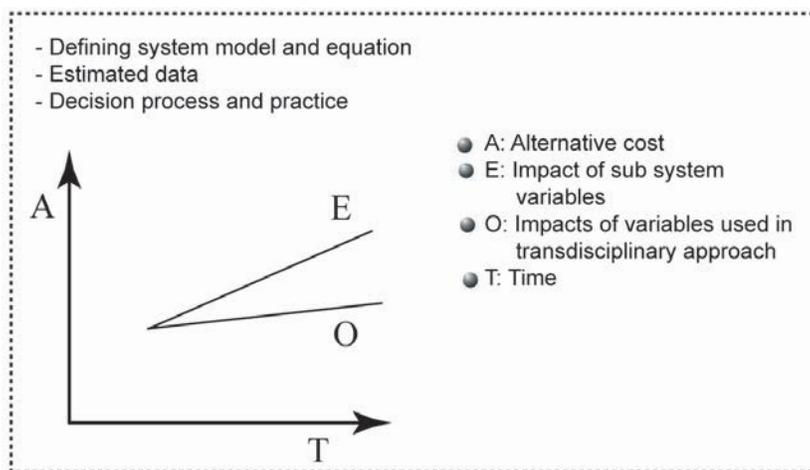
Anticipative analysis examines the solution of problem “ $P_1$ ” in time interval “ $t_1$ ” [11]:

- In analysis and research if the decision maker decides to solve the problem “ $P_1$ ” in time interval “ $t_1$ ” and use the estimated and required solution approach, analysis and research, the probability is relatively high that problem can be solved as an example with “1 unit cost”.
- If the solution in time “ $t_1$ ” is postponed for a definite amount of time, like five years, the structure of the problem might change. This might increase the alternative costs and the cost of solving the problem “ $P_1$ ”, and it may be 8, 10 or more units.
- If the problem “ $p_1$ ” is ignored in time much longer, the important changes in system dynamics, structures and problem environment might turn the problem into being unsolvable due to public, private decisions, environmental, sustainability, e.g. constraints.

Obtaining data, making observations and anticipating the future trends carries significant importance in scientific progress. Figure 15.4 [12] visualizes

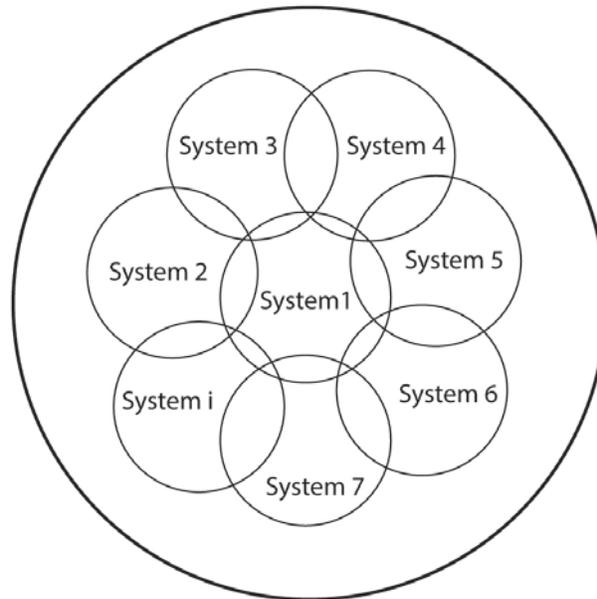


**Figure 15.3:** Minimizing information distortion and transdisciplinary science methodology (Güvenen, 2014).



**Figure 15.4:** Importance of strategic anticipation in research (Güvenen, 2015).

the strict relation between science methodologies and strategic anticipation. As it can be recognized from the figure the particular scientific approach has



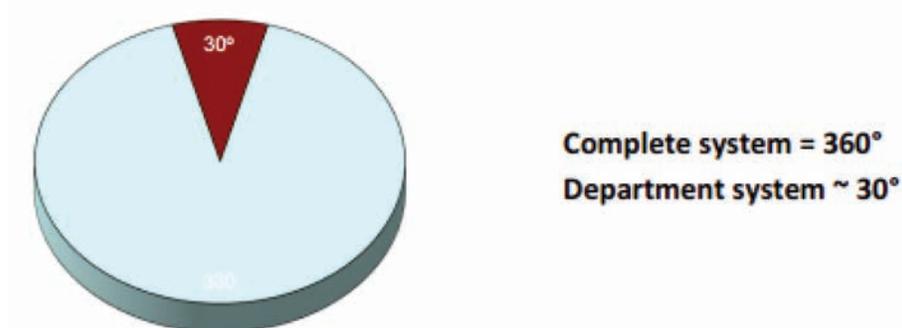
**Figure 15.5:** Complex structure of social sciences and anticipative analysis (Güvenen, 2013).

serious impact on the end result. Choosing an suboptimal scientific approach can end up with serious alternative costs in researches.

Figure 15.5 [13] represents the complex, intricate and interrelated nature of social science systems. Due to complex nature of these systems, anticipative analysis should be made by using transdisciplinary methods to converge to optimal result.

The collaborative and cooperative nature and problem targeted approach of Transdisciplinary science methodology can minimize the common problems and shortcomings of both pluridisciplinary and interdisciplinary science methodologies.

Transdisciplinary implies an integration-driven emergence of new disciplines, not just ad hoc collaborations. The transdisciplinary nature of current scientific and societal challenges—and the powerful new approaches enabled by the combination of traditionally separate disciplines—can be fully addressed only by a rethinking of current academic and government funding structures, as well as the traditional relationships among academia, the private sector, and government.



**Figure 15.6:** Transdisciplinary science methodology in education (Güvenen, 2013).

## 15.4 Transdisciplinary science methodology in education

One of the most important areas which transdisciplinary approach should be applied is the education system. The structural changes in science and society caused important changes in education system too. In 13th century when the first universities has been founded, the number of disciplines were only 7, however now there is more than 8000 scientific disciplines [14]. This paradigm shift shows why it is impossible to educate the future generations with the education system of the past.

The existing education structure generally is based on “department” system. “Department” dominantly transmits an education of subset and partial analysis. It does not provide the methodology of linking subsets within an iterative set approach of transdisciplinarity. Figure 15.6 [15] illustrates the relation between department system and complete system in education.

The department system neglects to dominantly the impact of science and knowledge elaborated by other disciplines which should be considered as complimentary to a given department teaching in a continous iterative approach. It tends to create an impact in the medium-long term; mechanistic, short-termist approaches in the society. The alternative costs of this subset and partial analysis approach are dominantly observed in the 20th century. 21st century science, research, analysis requires transdisciplinary methodology in order to deal with high complexities and provide feasible solutions. Students’ needs, characteristics, interests and personal learning processes occupy the core of transdisciplinary educational model.

It is important that the transdisciplinary skills to be taught to students during education include knowledge and skills required to identify, frame and address important scientific and practical problems that cut across disciplinary

boundaries. Such problems are complex and they require such skills as [16]:

1. Integration of problem framing and problem solving
2. Communication and collaboration among people from different disciplines and educational levels
3. Intelligent use of technologies and resources that support collective knowledge construction and extend human problem-solving capability.

Educational institutes are evolving to answer the demand for education of transdisciplinary skills. Actually universities are going through significant changes which they evolve from science-based , government funded institutions into “international know-how hubs” which is called third generation universities [17].

The concept of Transdisciplinarity and its practices which endogenize not only research, education but also daily life, decisions at the individual, corporate, institutional, nation state, international sphere must be a part of teaching, learning methodology for the earliest ages in school programmes.

Figure 15.7 [18] illustrates the basic traits of third generation universities. One of those traits and probably one of the most important, is transdisciplinary research. The fundamental research core of third generation universities are based upon the principles of transdisciplinary science methodology to ensure a competitive and modern university education.

Third generation universities through fundamental research, education, business and corporations continuous cooperation, complementary endogenize transdisciplinarity to universities. Their contribution increase the value added to research and education.

## **15.5 Transdisciplinary science methodology and ethics**

Figure 15.8 [19] above represents the relationship between the System 1 (S1) and System 2 (S2). S1 can be described as the structure of world dynamics targeting “humanity optimality”. S1 is the normative approach. System 2 (S2) represents the structure of world dynamics in 2016.

The dominance of S2 causes crisis and serious socio-economic problems. 2008 economic crisis is one of them. In the context of the 2008 world crisis, we observe that the world GDP was \$60 trillion at that time. However, the amount of financial operations in investment banking and markets were over \$600 trillion. Concerning this huge amount, we observe that there was not, and today there is not any legal, economic and regulatory framework concerning these operations and markets. It can be considered that it is appropriate to call it : a “crisis of ethics”.

As long as we live in a world which S2 is dominant, such crises, world level conflicts, wars, human traffic, drug traffic, degradation of natural resources

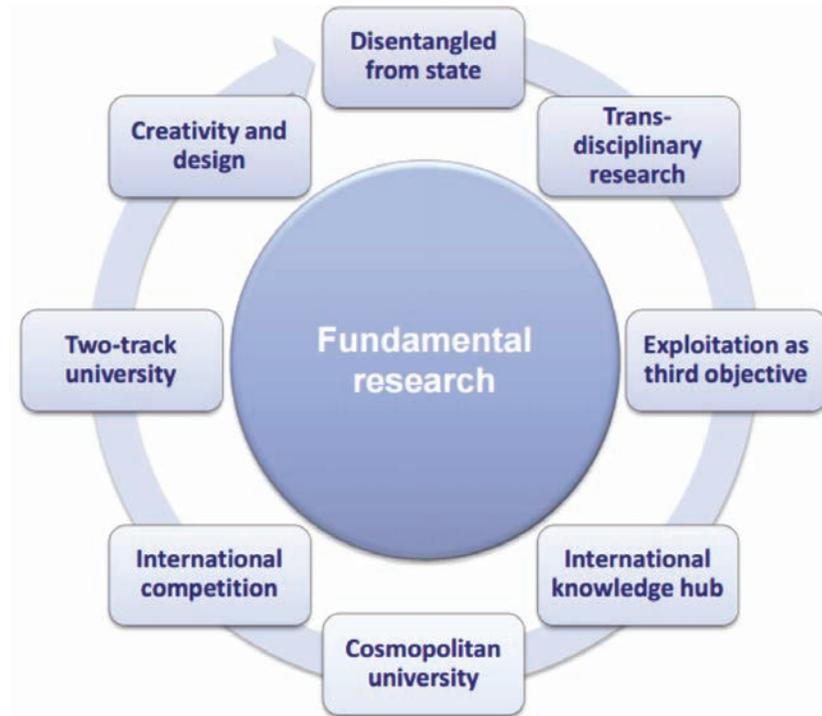


Figure 15.7: Third generation universities (Aarts, 2014).

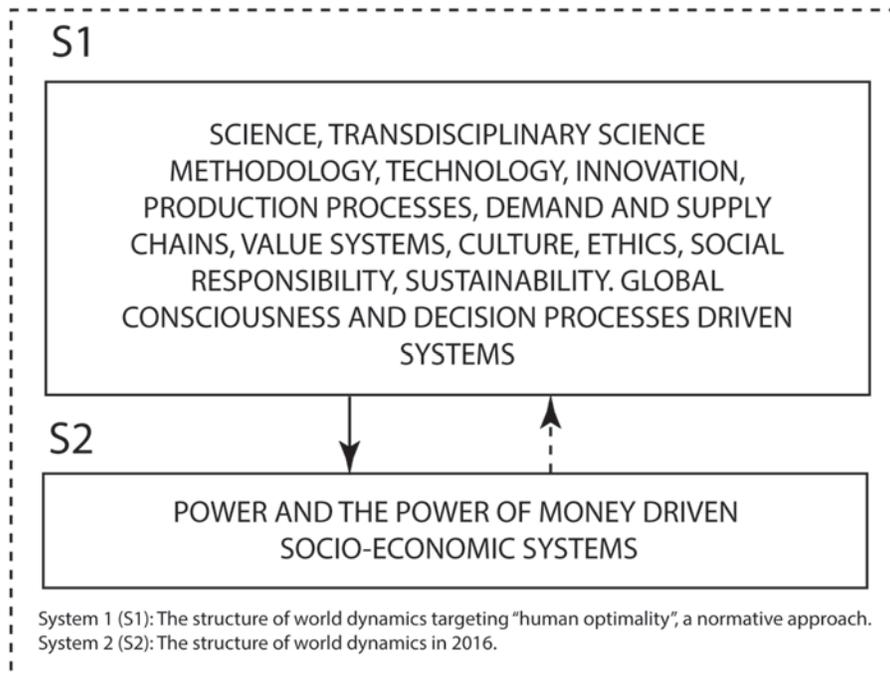
use, nature, environmental problems are unavoidable. We need to transform system into a brand new one which relies on human optimal; in other words we should focus on the values which S1 built on. Science, technology and transdisciplinarity are among the most important of those values. Ethics is a necessary condition for the set optimal [20, 21].

$$\text{Set Optimal} = \alpha_0 + \alpha_1x_1 + \alpha_2x_2 + \alpha_3x_3... + \varepsilon$$

“ $\alpha_0$ ” is necessary condition, which represents ethics whether at individual, corporate, institutional, nation state, transnational corporations, international organizations and international sphere levels.

## 15.6 Conclusions

Any search for a system optimal requires that ethics must remain constant in the dynamics of time and space at the individuals, institutions, corporations, nation states and international level. In preventing information distortion; the starting point, the initiator, the igniter constant should be ethics for the regulators and for the information system security practice.



**Figure 15.8:** World dynamics and some comments on socio-economic systems (Güvenen, 2013).

This approach should include the other explanatory variables in order to understand and minimize the error margins of the complex structures and decision systems which endogenize transdisciplinary science methodology.

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# CHAPTER **16**

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## Steps to an Ecology of Knowing, and to Teaching Embodied Transdisciplinary Hermeneutics

*Hans Dieleman, Autonomous University of Mexico City, Mexico*

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**T***his chapter explores Bateson's concept of the Mind as Ecology, in the context of philosophical ideas on phenomenology and embodied knowing, and neuroscientific ideas on embodied cognition. It equally links it with ancient oriental ideas regarding the relationship between body, mind and soul, and practices as meditation and yoga to nourish the body as an organ of perception. It then explores its consequences for our ways of knowing, and concludes that the Mind as Ecology needs to be nourished by an Ecology of Knowing including direct and phenomenological knowing, autobiographic and experience-based knowing, and formal and science-based knowing. The chapter argues that such Ecologies of Knowing can be realized through the practice of Embodied Transdisciplinary Hermeneutics. It finally presents seven steps to teach Embodied Transdisciplinary Hermeneutics. Two of these steps focus on the learning process as a whole, and five explore particular ways of knowing, and how to teach them.*

**Keywords:** Embodied cognition, transdisciplinary hermeneutics, phenomenology, reflective practice, creativity, dialogue, mindfulness, bodywork.

### 16.1 The Mind as Ecology

The title of this chapter is inspired by Gregory Bateson's famous book "Steps to an Ecology of Mind, collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology" [1]. According to Bateson, the mind is a network or system with a high level of causal and energy relations that process information in multiple and integrated ways. It compares, associates, senses, estimates

and calculates, and the outcome can never be reduced to simple inputs, but is always the result of highly complex mindful processes. For Bateson, the essence of all reality is its interconnectedness and inherent dynamism, and he devoted lots of time and effort to show us that we live with a basic misconception of the essence of nature and reality. We are very poor in understanding the world as ecology, and this is not only true for the world as a whole, but is equally true for our understanding of the parts, including our mind and body or, as I will put forward in this text, our knowledge of the world.

For Bateson, it was equally clear that our minds cannot be understood as disconnected from our bodies, as well as from our social and our natural environment. He illustrated this with the concept of “*man plus environment*”, and gave the example of how someone fells a tree with an axe. “Each stroke of the axe”, he explains, “is modified or corrected, according to the shape of the cut face of the tree left by the previous stroke. This self-corrective (i.e., mental) process is brought about by a total system, tree-eyes-brain-muscles-axe-stroke-tree; and it is this total system that has the characteristics of immanent mind” [2]. An essential consequence of thinking in terms of ecology is that, in the words of Bateson: “no part of such an internally interactive system can have unilateral control over the remainder or over any other part. The mental characteristics are inherent or immanent *in the ensemble as a whole*” [3] (Italics HD).

In this chapter I look at knowing as ecology, as a systemic activity that emerges out of the mind as ecology, and more in particular I look at transdisciplinary knowing as a form of knowing that is inherently and immanently in the ensemble of ways of knowing. My argument is that transdisciplinary hermeneutical knowing is the only way of knowing that respects Bateson’s idea of man plus nature and the mind as ecology. Before entering in transdisciplinary knowing, I will first explore the idea of the mind as ecology within the context of philosophical ideas on phenomenology, contemporary ideas coming from the field of neurosciences, and ancient Buddhist and Hindu knowledge. Then I will present my ideas on transdisciplinary hermeneutics, as a practice of a unifying transdisciplinary form of knowing. Then I will present 7 steps that together create the conditions for a comprehensive way of teaching transdisciplinary hermeneutics, rooted in embodied and embedded ways of knowing and the mind as ecology.

## 16.2 The Embodied/Embedded Mind

Bateson’s concept of “*man plus environment*” is echoed in contemporary concepts of embodied, embedded, extended, situated or distributed cognition [4]. There is an ever-growing recognition that the idea of the mind as an abstract information processor is up to revision. Most neuroscientists today acknowledge that the mind must be understood in the context of its relationship to a physical body that interacts with the outside world [5]. As Damasio convincingly argues, bodily and emotional experiences are of key importance in our

capacity of reasoning [6]. There is no intellect-emotion divide, even though the loci of both are different. Emotions are mainly situated and stored in the body while the intellectual processes take place in the brain. They are however totally entangled and interrelated, with emotions feeding the intellectual processes [7]. Moreover, our brain does not serve us mainly to engage in abstract and theoretical thinking, but is first and foremost the control system of our body, a body that moves and acts in real-world surroundings [8]. This implies that the environment is an integral part of the cognitive system, as Bateson expressed with his concept of “*man plus environment*”. The information flow between mind and world is so dense and so continuous, that the mind alone cannot be seen anymore as a meaningful unit of analysis.

Phenomenological thinkers like Theodor Husserl, Martin Heidegger, Maurice Merleau-Ponty and others laid the philosophical groundwork for the embodiment/

embeddedness thesis. Merleau-Ponty argued that it is not our consciousness but rather our perception that plays a key role in our understanding of the world [9]. Before him, Husserl introduced the concept of the “living body” (*Leib*) in contrast to the Cartesian “body” (*Körper*), to demonstrate that perceptual meaning is derived from the motions that the body makes. He emphasized the importance of the ‘lifeworld’ as the concrete world that surrounds us, and “is given through perception” [10]. It is an empirical world that we can relate to in phenomenological, embodied and experiential ways, instead of an abstract world created in mere conceptual ways. Heidegger introduced the concept of being-in-the-world (*Dasein*), indicating that a human being cannot be taken into account except as being in the middle of a ‘here and now and everywhere around’ world. It is the world we interrogate, consider and are concerned with, a world in which we accomplish things, make use of things and produce things [11].

We cannot isolate our minds from our bodies, Edgar Morin argues, and there is no superior stage of reason that has the capacity to dominate, sublimate or eliminate emotions. According to Morin, we are no *Homo Sapiens Sapiens*, but we rather are *Homo Sapiens Demens* being both *sapiens* – wise – as well as *demens* – irrational, creative, imaginary and prone to unrestricted emotions. We are characterized by a brain-mind-culture loop, as well as with a reason-emotion-impulse loop and an individual-society-species loop [12]. We cannot isolate our minds from our bodies and ourselves from our societies or communities, and it does not make sense to fight ‘*demens*’ so reason can triumph, we rather try to balance and integrate the two.

In stricter corporal terms, neuroscientist Antonio Damasio conceptualized the importance of the body through the introduction of his theory of the so-called “somatic markers” [13]. Emotions are somatic markers that constantly regulate the homeostatic balance of our body. In doing so, they continually observe and register threats and opportunities, and inform us on how to act in the face of those opportunities and threats. They are important helpers as they create, usually in non-conscious ways, a framework for decision-making,

putting information in the context of what is needed in terms of both risks and opportunities. According to Damasio, this neuronal signaling, carried out by neuroreceptors, is the base of a chain or hierarchy of various stages of knowing, where each stage builds upon the previous in chain. Based on this idea, he distinguishes among three conceptions of the 'self'. The first is the 'protoself' that constantly, and unconsciously, detects and records physical changes, relevant to maintaining homeostatic balance. The second is the 'core self', where emotions are converted in feelings, meaning that we become aware - conscious - of the changes occurring in our bodily state, and the corrections our body carries out or is asking for. The core self is the self we all recognize as "our body" with pain, fatigue, hunger, desire, itchiness and more, and should be seen as an active "body-mind-consciousness complex" on the level of single feelings. The third stage is that of the 'autobiographical self' that places feelings in the context of experiences, using memory. Here we create our extended consciousness through contextualizing feelings and emotions in the context of previous experiences and higher - abstract - thoughts and concepts. It is on this level that we "are-in-the-world", integrating concepts, feelings and experiences; remembering, comparing, associating and reasoning, integrating certain forms of information in the context of experiences, feelings and other information, thus creating a coherent view of reality and of ourselves.

Finally, there is growing conciliation between Western and Oriental (Buddhist and Hindu) thinking on the body-mind-brain relationship, and on the body itself. The scientific field of neuroplasticity has come to recognize that, in contrast to the assumption generally held just a few decades ago, our brain is not fixed and is open to change, while practices in meditation, yoga and mindfulness do have the capacity to stimulate and realize such changes [14]. There equally is scientific proof for the important assumption in both Buddhist and Hindu thinking, that we have next to our physical body an energetic body that plays important roles in our emotional and energetic stages of being. Such proofs are realized with recently developed technology that can measure energy fields or energetic bodies [15 ;16]. These insights amplify our understanding of the relationship between emotion, reason, body and environment, and give room for new practices of consciously strengthening that relationship, through bodywork activities like meditation, mindfulness, conscious breathing, acupuncture and more. It opens new ways for ancient practices as Reiki, Tantra, Shiatsu and others to be integrated in new practices based on the idea of the wholeness and unity of the body and the mind.

### **16.3 The Mind and Our Ways of Knowing**

What are the consequences of embodied cognition and seeing the mind as ecology, for our ways of knowing and our education? Philosophical studies dealing with new technology explore this question in the context of modern technology like computers, the Internet and cellular phones [17]. Are such technologies merely contextual and helpful but outside of our inherent cognitive processes,

or are they an integral part of our – extended – cognition? In this context, Michael Wheeler asked the key question: is the same way of knowing possible with and without the extension? If it is possible, we cannot talk about extended cognition. But when the same way of knowing is not possible without the extension, it is justified to talk about extended cognition [18].

The question is very relevant in all areas of knowing and knowledge. Many forms of knowing, like experimental knowing as in acting upon and connecting with the world, are not possible without having “the world” present. We cannot feel, smell, hear, touch, taste, act upon or create, when there is nothing concrete to feel, smell, hear, touch, taste or create. In all of these ways of knowing, the environment is an inherent and immanent part of the mind. The study of so-called Qualia provides us with interesting insights in this context. Qualia are individual instances of subjective, conscious experiences like pain, the taste of wine, or the perceived redness of an evening sky. In his article “Epiphenomenal Qualia”, Frank Jackson explains why Qualia cannot be reduced to concepts, while he gives the very interesting example of Mary the color scientist:

*“Mary the color scientist knows all the physical facts about color, including every physical fact about the experience of color in other people, from the behavior a particular color is likely to elicit to the specific sequence of neurological firings that register that a color has been seen. However, she has been confined from birth to a room that is black and white, and is only allowed to observe the outside world through a black and white monitor. When she is allowed to leave the room, it must be admitted that she learns something about the color red the first time she sees it – specifically, she learns what it is like to see that color”* (<sup>19</sup>Jackson, 1982: 130).

Jackson’s example shows that our mind cannot function in a complete way - as ecology - when it is only partially nourished, with only concepts, abstractions and scientific data. Our minds need to be nourished with a rich ensemble of ways of knowing: concepts, data, practices, experiences, cultural codes and wisdom, sensorial information, emotions, feelings, color, smell, vibrations, revelations, reflections and more. Bateson’s concept of the mind as ecology tells us that our mind is inherently transdisciplinary as it, in principle, always compares, associates, senses, estimates and calculates, while none of these activities alone can have unilateral control over the remainder or over any other part. Yet the functioning of the mind as ecology depends on its nourishment or, in other terms, on the inputs it receives from our body and from our environment, next to abstract and conceptual information. The concept of the mind as ecology has enormous consequences for our ways of knowing. It tells us that it is impossible to get a full understanding of the world without bodily being present in that world.

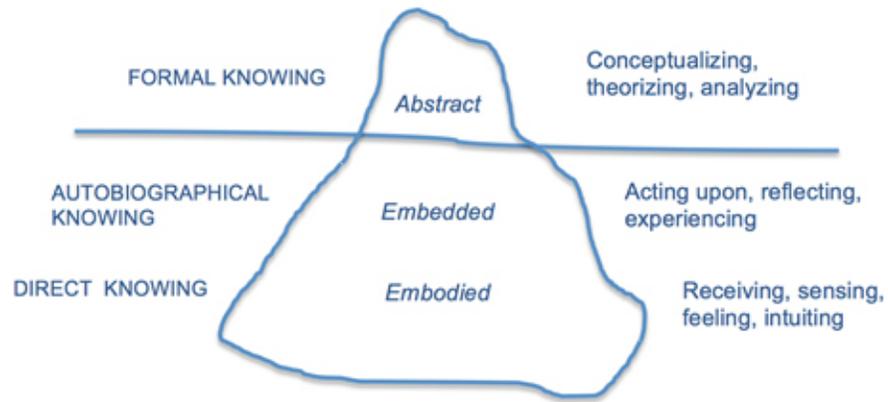
The example of ‘Mary-the-color-scientist’ is very strong, as she is totally, in a 100% form, deprived of one specific way of knowing. That is exceptional,

but many of us experienced something similar in less extreme forms. Most of us learned to understand reality not in experiential ways, integrating body, mind and environment, but in rather formal and abstract - Cartesian - ways, with a mind that was basically disconnected from our body and our physical environment. Many children in the history of modern education learned to understand nature and society merely from books, without going out in nature or in the streets to see, feel and relate in sensorial or direct ways. In higher education the fragmentation and isolation is even worse, due to the disciplinary and theoretical focus of academic research and education. Fragmentation and isolation however is not restricted to higher education. In most schools, teaching still takes place in a sequence of lessons in mathematics, followed by geography, history, physical education, etc., without any class that teaches us how to integrate these subjects. Likewise, most of us never really learned to be in contact with our feelings and emotions or to train our senses. We never really learned to be in contact with our bodies and unfortunately, this is still the reality for many children today, despite of the change realized in the past decades.

We are naturally transdisciplinary beings that – in principal - always know through our ecology of mind, but education often is providing us with a poor and homogeneous input of knowledge. As a consequence, we never really *learn* to master a transdisciplinary/ecological knowing process. This, in turn, hinders our capacity to balance heterogeneous knowledge components, and to find equilibrium among our emotions, feelings, intuition, experiences, cultural wisdom and the outcomes of logical thinking. We have poor literacy in many of these ways of knowing and thus, in an integrated way of knowing.

## 16.4 The Importance of Transdisciplinary Hermeneutics

Basarab Nicolescu [20, 21] formulated his transdisciplinary project in part as a response to the problem of education just mentioned. He asks attention for the high level of fragmentation of our knowledge, as science gets ever more divided into disciplines and specializations, leaving us behind with a fundamentally fragmented understanding of the world. He equally asks attention for the loss of intimate contact with the world that we now know merely in terms of abstract descriptions, theoretical constructs and mathematical formulas. We create knowledge *in vitro*, Nicolescu argues, like in sterile and isolated glass bottles, instead of knowledge *in vivo*, situated in living ecologies [22]. He makes a plea for forms of knowing that are – in his terms - in between, across and beyond the disciplines, rooted in a more direct and intimate relationship with the world. This allows us to see and experience the world as a living subject - a lifeworld - and relate with it in more caring and responsible ways. He follows a line of thinking that goes back to Husserl's phenomenology and the hermeneutics of Heidegger and Gadamer. He makes a plea for transdisciplinary



**Figure 16.1:** The iceberg of transdisciplinary knowing (self generated).

hermeneutics that integrates the knowledge coming from traditional academic disciplines, but equally from poetry, art and quantum physics. The aim of transdisciplinary hermeneutics is to integrate and unite these different ways of knowing thus creating “meaning of meaning” beyond any single way of knowing and any single level of reality [23].

Over the past years I worked on a concept of transdisciplinary hermeneutics that I see as comprised of two basic dimensions or axes [24, 25]. The first is an identification of different ways of knowing, that I conceptualized in terms of three generic ways of knowing, that I now label as formal, autobiographical and direct knowing. The second axe is the actual practice of transdisciplinary hermeneutics, the act of knowing in an integrative and unifying way. In terms of the first axe, I look at knowing as a hierarchical complex, starting with embodied and direct knowing – neurological receiving, feeling, intuiting, sensing – followed by autobiographical knowing realized in acting upon, reflecting and experiencing, up to formal and abstract knowing as in conceptualizing, theorizing and analyzing (see Figure 16.1).

The challenge of transdisciplinary hermeneutics is to learn to master all of these ways of knowing – with their specific organs of perception – independently from each other, and to then combine them to create meaning of meaning. Our bodily movements and neuroreceptores are an organ of perception, and so are our feelings regarding our bodily state. Our emotions form an organ of perception, and so do our imagination, revelations, insights, past and present experiences. Scientific ways of knowing equally form an organ of perception, with rather distinct characteristics. I broaden the meaning of ‘organs of perception’ beyond the original meaning Goethe gave it – as feeling and feelings-intelligence - and use it to identify any method, activity or way of knowing of a particular level or part of reality. The complex of all of

these organs of perception allows us to know in multiple and rich – transdisciplinary - ways, and none of them should be excluded or used in isolation. It is through a mix of knowledges and ways of knowing that we nourish the mind in rich ways and make it function as real ecology. It equally allows us to integrate them with cognitive knowing of concepts, ideas, theories and facts, as with the internally stored memories of previous life experiences, cultural wisdom and tradition. It also offers us the opportunity to incorporate and integrate aesthetic experiences, with colors, forms, textures, sounds, temperatures and smells, as manifestations of emerging insights and recently revealed revelations.

I like to visualize this as an iceberg where abstract and formal knowing is visible, and embodied/embedded knowing is not. This is inspired by the metaphor of the iceberg used in organizational studies [26]. In organizational studies the top of the iceberg represents the formal goals and objectives of an organization, together with its structure and finance. This part is visible and often the main subject of discussion. The invisible part of the iceberg stands for the culture, the habits, the implicit norms and values that are too often taken for granted. In knowledge it is not different, we focus on the formal disciplines and ways of knowing, and forget about all that is in between, across and beyond those disciplines. This knowledge however is the basis of disciplinary and formal/abstract knowing, as it provides context and meaning. It allows us to turn knowledge *in vitro* into knowledge *in vivo*, creating connection and an intimate relationship with the world. It is a much bigger conglomerate of knowing than the mere formal and abstract knowledge we focus so much on.

The second axe of transdisciplinary hermeneutics is about the actual engaging in the knowing process of connecting us with our body and our environment. I see it as an art, rather than a science, and as a dance with the world, tuning in with its rhythms, vibrations and movements [27]. It is a double dialogue with the rhythms, vibrations and movements of our inner self, as well as those of the outside world. It is highly sensitive and mindful, and allows us to integrate the bodily awareness of our internal energies with those of the outside world. Whatever we want to know, a physical space like a city, a landscape or a public space, a community, organization or group, or if we want to know a person, a patient, a client or a co-worker, the dialogues have similar dynamics. We use our senses, we see, hear, listen and if possible we touch and smell. We equally feel in a literal sense, emotions, vibrations, tensions and harmony, and we try to build bridges between those outside movements and our own internal movements. In this way we build images an impressions or a bodily map of what or who we are knowing. We observe, sense, perceive and feel, yet equally, and possibly at the same moment, we interact in the sense of *creating* movements, connections and possibly transformations. We enter in processes of learning and knowing by doing, through reflective practice and acting upon. In doing so, we create experiences with the person, organization or space we are engaged in. Finally, yet again this may be simultaneously, we collect data, analyze and conceptualize what we see, hear and, we include that

what is obscured and invisible for the senses. We study history, relationships, important events, future plans and more. In this way, we allow ourselves to create meaning of meaning beyond any single way of knowing.

It is about disclosure in the Gadamerian sense of the word, as in tuning in and listening to *how we allow the world to disclose itself* [28]. These words – how we allow – the world – to disclose itself – are essential and I like to explain them making use of Nicolescu’s distinction between Real and Reality. For Nicolescu, Real is simply ‘all that is’, and is in principle infinite. However, it is ‘forever veiled’, since we never will be able to ‘grasp’ it completely [29]. We always have a limited view on all that is to be known and as a result, Reality is always much more limited than Real. We always only ‘see’ in terms of the methods and language we use, making a selection of ‘all that is’, based on our capacities of sensing and observing, our capacities of comprehension, apprehension and imagination, and our organs of perception. It is in this context that transdisciplinary hermeneutics is crucial, as a way to allow the world to disclose itself in multiple ways, on various levels of reality. It is realized in cyclical, iterative or spiral ways with our inner self as well as with a concrete lifeworld, with the aim of creating, what Nicolescu calls ‘meaning of meaning’, which is acquired through the interconnections of all of the reality we include in our process of disclosure.

It is important to mention that I see the term disclosure in a Gadamerian way, rather than in a Heideggerian way. The concept of “disclosure” is closely linked to the work of Martin Heidegger, who saw disclosure as revelations or insights that come to us from the depth of the Earth. Heidegger assumed that these revelations by definition revealed true knowledge, because they come from deeper levels of wisdom [30]. I rather follow Hans-Georg Gadamer’s interpretation of disclosure, as ‘dialogical truth’, where disclosure brings insights to the surface that still are open to a dialogical process of questioning and testing, to assess their credibility [31].

Meaning of meaning or transdisciplinary knowing is therefore an emerging property of the activity of engaging in transdisciplinary hermeneutics as a systemic activity including heterogeneous forms of knowing on various levels of Reality, and cannot be reduced to knowledge of the parts. I call it the creation of ‘Ecologies of Knowing’ that are, like any ecology, systems of knowing with their own system elements and dynamics, like their emerging properties, feedback and feed-forward loops between the various ways of knowing and organs of perception. Transdisciplinary knowing is not the sum of direct, autobiographical and formal knowing, but is a multiplier creating something beyond the three forms of knowing [32]. It is in the “beyond” where meaning of meaning can be found and we need to create complex systems in order to be able to allow such emerging – beyond - properties to manifest themselves.

## **16.5 Steps to Teaching Embodied Transdisciplinary Hermeneutics**

Can we convert the previously presented ideas into concrete steps to teach and learn embodied and embedded transdisciplinary hermeneutical knowing? In the subsequent part of this chapter, I will make an attempt to do so, distinguishing among 7 different steps that touch upon different aspects of the ways of knowing previously outlined. The first and the last step focus on the learning process as a whole, and formulate some conditions for the learning process to be successful. Steps 2 until 6 focus on particular ways of knowing.

### **16.5.1 The First Step: Creating a Learning Environment of Being-in-the-World**

The first step is to stop thinking in terms of most of what we know about traditional learning and teaching. When we imagine a school for embodied and embedded transdisciplinary hermeneutics, its central orientation must be towards the practice of tuning in and listening to how we allow the world to disclose itself. It is a school for being in the world, both the external world in which the student is embedded, as the internal world in which he or she is embodied. It is a school where education is not based on teaching units - knowledges, skills, aptitudes or attitudes - but on facilitating students to build relationship with their lifeworld. Connectivity is key, as is the shaping and sensitizing of the various organs of perception. Students do not enter the school in the morning and leave in the afternoon, to spend most of their time in classrooms, engaging in cognitive learning activities. They do have in-house activities, but the school is primarily a point of many points, where students prepare themselves to go out, allowing a particular lifeworld – a concrete and tangible environment – to disclose itself, on multiple levels of reality. It is the place where they return later to dialogue and share experiences, impressions and images, and to do additional studies in the form of data collection and analysis. But in that order: first connecting with the lifeworld, and only later data collection and analyses. The school is totally situational, problem-based, participatory and experiential, from day one onwards. Fieldwork is not to test previously learned insights, theories or concepts, but to build connectivity and apprehension.

### **16.5.2 The Second Step: Training the Body to be an Organ of Perception**

The second step focuses on training the body to be a better organ of perception. Most of us never really learned to use our body as an organ of perception, and this training or teaching should be added to the standard list of skills in – preferably – all schools and educational programs. Listening to our body, breathing in conscious ways and being mindful in all our bodily processes,

should be seen as a skill, like a communication or a collaboration skill. It opens doors to knowledge and connectivity with the world that are otherwise closed. It equally contributes to our long-term personal development, as the brain changes under the influence of prolonged practice of meditation, yoga, mindfulness and various artistic practices.

This step is mainly realized as a series of in-house activities, with practices that have the capacity to clear our minds and to open ourselves to the outside world, in ways very different from traditional knowing. Within the context of transdisciplinary hermeneutical knowing, these practices *lay the groundwork* for what I previously called direct and phenomenological knowing. This is a truly embodied form of knowing which presents itself not as a result of deliberate thinking processes, but rather emerges in moments when we consciously try “not to think”, and clear our minds. In such moments we open ourselves to receive insights, revelations or illuminations that present themselves, in the words of Charles Sanders Pierce, “just like that”, in “a flash” [33].

The very first activity to engage in should be to teach students how to breathe consciously, and how to nourish well their body and brain with oxygen. We normally take this most basic – yet most essential - human activity for granted, even though many do not breathe in adequate ways. Yoga essentially is a practice of breathing in different bodily positions thus nourishing various parts of the body, while the beneficial effects of yoga are now scientifically proven and recognized [34]. Meditation practices stimulate mindfulness – a state of intensified attention to the present – as well as our intuitive capacities of knowing, and these effects as well are scientifically proven [35]. Such practices literarily nourish and train the body to be a better organ of perception, and should be standard practices in all training in transdisciplinary hermeneutics. This training may also include bodywork, as a group of healing techniques to liberate blockades within our energetic bodies. Exercises to train embodied interactions with others – like martial arts - may be included, as well as the art of consciously touching the body, or the use of body language. Various artistic activities can be included, like creative writing, painting, dancing or acting, as well as simple physical activities like walking, hiking or running.

They all have the potential to (re)-connect us with our body and our emotions, and to make our body better organs of perception. Training them should be the first step in all education, as our body is totally entangled with our brain and our knowing capacities depend on this entanglement.

### **16.5.3 The Third Step: Engaging Students in Phenomenological Ways of Knowing**

While step two prepares us, step three invites us to really *engaging* in direct and phenomenological knowing, and aims at deepening our way of ‘being in the world’, through entering in contact with our lifeworld in embodied, embedded and mindful ways. It is about connecting and feeling the environment, allowing it to disclose its essence, energy, forms, colors, movements and sounds.

This step is obviously mainly realized outside of the school, in a particular organization or community, in a natural environment or in contact with other people. One of the first to write about knowing as direct sensorial experience was Johann Wolfgang von Goethe. For him it was a way of creating images in the mind (imagining), rather than constructing categories or assigning formal characteristics to phenomena (conceptualizing). He looked at conceptual knowing as subjective, since we are imposing our ideas (concepts) on reality. By contrast, he looked at feeling the world and restraining as much as possible from judgment and verdict, as the objective way of knowing [36].

An essential characteristic of direct and phenomenological knowing, in the context of transdisciplinary hermeneutics, is that it allows us to see, feel, experience and therefore know in ways that are very different, and complementary, to other ways of knowing. In direct or phenomenological ways, we can know what remains to be veiled when we only know in logical ways. In this context as well, Gregory Bateson made valuable observations. In his book “Mind and Nature” he asked: “What is the pattern that connects the crab to the lobster and the orchid to the primrose, and all four of them to me? And me to you?” [37]. Bateson showed that logic is very limited in answering such questions, as it is above all a matter of abduction that requires a certain sensibility to the patterns that connect [38]. Direct knowing, through intuition, abduction, feeling and sensing, opens up a category of knowing that otherwise remains closed, and opens levels of reality that otherwise remained veiled.

In process terms, the essence is to be-in-the-world and to be-in-the-presence. In this context, Otto Scharmer formulated his so-called U-shaped theory, which visualizes both a downward movement (the left part of the “u”), and an upward movement (the right part of the “U”) [ ]. The downward movement represents the process of acquiring knowledge – a downloading process, while the upward movement represents that what we do with that what we learned and acquired, an uploading process. Scharmer emphasizes the importance of suspending the download of past patterns and past ways of knowing, and advocates instead to see with fresh eyes through what he calls ‘sensing from the field’ as a phenomenological way of connecting with the world. The important claim he makes is that this phenomenological way of knowing allows us to be more creative in applying our knowledge, in the upward or uploading movement on the right side of the ‘U’. It helps the mind to (re)-arrange information in free-floating ways, and allows us to tune in with the future that we see emerging.

Frances and Wride describe how presencing, direct or phenomenological knowing, sensing from the field or being sensitive to the patterns that connect, is taught and practiced in the Schumacher College [40]. A preliminary stage, they explain, is to ‘feel the world’ with its particular energy and presence. This is followed by a stage of ‘exact sensory perception’, as a conversation with the world suspending all form of personal judgment and evaluation. The next stage is that of ‘exact sensorial imagination’, as a way of consciously recreating the observed phenomenon inwardly. Various models exist that can

help us create a concrete educational program to teach and facilitate students to engage in direct or phenomenological knowing. It is essential that this enters teaching practices in all education, and certainly in teaching transdisciplinary hermeneutical knowing.

#### **16.5.4 The Fourth Step: Facilitating Students to Engage in Reflective Practice**

The fourth step facilitates students to know in experiential and dialogical ways, through engaging in reflective practice. The difference with the previous step is that the students now aim at transform the world, like felling a tree, working with a community or an organization, a technology, a patient, a natural area or a plant. Reflective practice is acting upon the world, inviting her to “talk back” in the form of telling us why some actions lead to positive change and others not. In terms of Paolo Freire: “The act of knowing involves a dialectical movement that goes from action to reflection and from reflection upon action to a new action” [41].

As Donald Schön explains, it is like engaging in a double dialogue with on the hand the situation in front of us and on the other hand our inner self [42]. It is like an open experiment that serves to transform that what we act upon, while it simultaneously generates a new understanding of that reality in our mind. An important characteristic of reflective practice is its experimental nature. It essentially means engaging in an experiment that we do not (aim to) control completely [43]. We are part of it, but do not control it entirely, thus allowing the process to go in unforeseen and unplanned directions. This really stimulates intrigue, surprise and wonder and allows for “emergent properties” to present themselves, as in ecopoiesis [44]. This as well serves creativity and the creation of something new, rather than the repetition of that what we know and have.

A second essential aspect of reflective practice is that we engage in the outside world using our inner mental map that is like a storage place of all our previous life experiences, in the form of a variety of images and descriptions, experiences, formal knowledge, emotions, tacit knowledge and more [45]. Engaging in the double dialogue of reflective practice means seeing the world in its full complexity, combining and associating our senses with our emotions, with our previous experiences and with formal knowledge, all around certain actions and practices we engage in at such present moments. Because of that, it is truly transdisciplinary as it allows us to work over various levels of reality integrating various ways of knowing.

Situational, problem-based, participatory or experiential learning has similarities with reflective practice as presented here. There are however also important differences. A lot of situational or problem-based learning, especially in higher education, is restricted to a mere cognitive, analytical and conceptual way of exploring the outside world. They usually do not include our inner map and how we feel or sense the problem or situation. Moreover,

the projects are usually very well planned and are considered to be of better quality, precisely when they are well planned. This leaves much less room for surprise and intrigue, and for unexpected emerging properties and ecopoiesis. That is why it is important to ensure that reflective practice uses the whole mental map and links in with feelings, emotions and experiences, and has an open character, leaving room for the unexpected.

### **16.5.5 Step 5: Facilitating Students to Engage in Dialogue**

The fifth step teaches students the art of dialogue, as a really transdisciplinary hermeneutical practice. As Mikhail Bakhtin pointed out, dialogue is not only a concept related to communication or discourse, but expresses fundamental aspects of how we know reality [46]. A particular way of expressing in words how we see the world, he argues, illuminates some aspects of it yet obscures others. Therefore, a more comprehensive understanding of the world by definition implies ‘heteroglossia’ or multilingualness. In a novel this is presented in the different storylines that interact with each other, and in social life, heteroglossia is found in the words of different classes and communities that dialogue with each other. It also is found in the different levels of reality that we include in dialogue, as the levels of logic, emotion, experience or revelation. A true dialogue has heteroglossia and is therefore transdisciplinary.

David Bohm characterized a dialogue as a stream of meaning flowing among and through those engaged in the act of dialoguing. The aim is not to arrive at one single truth or best way of seeing reality, but to arrive at shared meaning relevant for those involved in the dialogue. The essence is creating an open dialogue space as a listening circle, which is little by little filled with heterogeneous contributions allowing the participants to build upon that what all bring forward [47]. Participants do not act upon each other by means of agreeing or disagreeing; they all contribute to the dialogue from their own perspective, yet they may be encouraged by the contributions of the other.

The dynamics is as follows. The group selects a certain topic – a public space, a community, a polluted river, domestic violence – (basically any topic is possible) and sits down in a circle. All participants reflect upon the common topic in any way they want: descriptive, theoretical, persuasive, poetic, metaphorical, through an experience, a proposal, a particular feeling. Little by little, the open space in the middle of the participants is symbolically filled with the heterogeneous contributions of the participants, and serves two purposes. It shows the rich – transdisciplinary – way of looking at the selected topic (the outer world), and serves as a mirror for each participant as it touches upon their internal mental map (the inner world). Each participant learns, in an experiential way, the many and diverse ways to understand and relate us with the chosen topic and, through that, with the world in general. It is a genuine experiential way of knowing through conscious dialogue.

Yet it needs to be learned, taught and practiced. According to Richard Sennett, engaging in dialogue is like a craft that goes beyond a mere logical

exchange of words, allowing us to feel, see and imagine the relevance of all that is put forward in dialogue [48]. It is a specific form of both problem seeking and problem-solving that, like regular craftsmanship, involves combining head and hands and depends on a certain sensitivity and responsiveness to the materials one works with. It requires practice, discipline and concentration to master, and calls for a certain disposition and way of being in the world. Therefore, training in mastering dialogues as well should be included in the education of transdisciplinary hermeneutics, and is an essential step in creating ecologies of knowing the nourish the mind as ecology.

### **16.5.6 The Sixth Step: Facilitating Students to Learn in Analytical and Conceptual Ways**

After exploring the world through conscious picture building, reflective practice and dialogues, it makes sense to bring the exploration process to the level of analytical and conceptual knowing, in terms of formal descriptions, hypothesis and generally accepted theories or concepts. This brings us to the sixth step of cognitive, analytical and concept-based ways of knowing. In higher education, it involves the well-known variety of activities as searching for and analyzing literature, building a conceptual – theoretical – framework, and doing empirical research using adequate scientific research methods. In basic and secondary education it involves learning facts and figures, from mathematics towards history or geography. My intention is by no means to exclude this part of formal and cognitive knowing, as this as well opens particular doors to specific knowledge, which otherwise remains veiled. On top of that, a scientific way of knowing requires a methodological mind that I see as a real virtue, more than worthwhile studying and teaching.

Yet, facts and figures, like theories within ever more specialized scientific domains, need to be contextualized. After all, this is one of the essentials of hermeneutics: a practice of understanding the whole in the context of the parts, and vice versa. Disciplinary knowledge should be contextualized in experiential and direct knowing, as it should be evaluated in the context of an interdisciplinary framework, allowing the specialized knowledge parts to be integrated in larger bodies of knowing. In this context, it is highly recommendable to teach students to construct and use mind maps that characterize a certain part of reality through linking different conceptual ways of seeing it. The mind maps I envision here are conceptual and have the virtue that they position a part of reality within the context of multiple concepts and disciplines, creating a rich conceptual ecology of knowing.

This sixth step of cognitive, analytical and conceptual knowing should focus on teaching students a methodological mind, and should teach them an interdisciplinary and systemic way of working with concepts, data and scientific insights. Finally it is essential that students learn to contextualize scientific knowledge in the larger knowledge ecology they create in life in general, and through the steps previously outlined in particular.

### **16.5.7 The Seventh Step: Seeing Education as a Dispositive of form and Content**

The seventh and last step sees education as a dispositive of form and content. Education has objectives, strategies and content, yet equally has a form. This form is not only represented in the teaching materials but equally in the physical and social context or environment where it takes place. It is a heterogeneous ensemble consisting of discourses, institutions, architectural forms, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral and philanthropic propositions and – very crucial – it applies to both that what is said as much as that what is unsaid. Any educational institution is therefore, in terms of Foucault, an “apparatus” or “dispositive” where the whole of the multiple elements work together to realize the objective [49].

When thinking in embodied and embedded education to teach transdisciplinary hermeneutics, it is immediately clear that the environment is part of the student’s minds and must be shaped – pedagogically, socially, culturally, physically, architecturally – in such ways that it supports the objectives of the educational programs. It is obvious that the school needs spaces fitted to do yoga and meditation, and that it needs to be an open space where students go out to connect with the world in phenomenological ways, and act upon the world in reflective ways. There will be a room for computer use, as there will be rooms for dialogue, but there will be little or no space for traditional classrooms and neither for traditional teachers or traditional rules and traditional expectations. In terms of the ‘U’ theory of Otto Scharmer, it cannot be build by downloading old ideas of the past and present, but must be created by uploading new ideas that we can create when we tune in with the emerging future we want to realize.

It depends on a culture that embraces embodied and embedded ways of knowing, and looks for meaning of meaning beyond single ways of knowing. This must be expressed by the teachers in word and in their actions, in the rules and regulations of the school and in the way the school is physically build and spatially organized and designed. The unity of teaching is not any longer the student, but the orientation is towards how the student tunes in and listens to how he or she allows the world to disclose itself. It is in other words focused on the complexus body-brain-social-physical-environment, in particular and concrete lifeworlds.

## **16.6 Conclusions**

In this chapter I explored the concept of embodied and embedded mind, and the consequences this has for knowing en education. I observed that the mind as ecology, a concept introduced by Gregory Bateson, needs to be nourished by an ecology of knowing, in order to function well. This ecology of knowing consist of uniting and integrating various ways of knowing, direct, autobio-

graphical and formal ways of knowing. I then explored the consequences of this for education, and formulated seven steps for an education in embodied transdisciplinary hermeneutical knowing. The final question I want to raise is how a teacher should function within this metaphor of knowledge as ecosystem, and the idea I want to put forward is to see the teacher as a gardener and a steward, whose task is to facilitate and help creating the right conditions for the knowledge ecosystems to be and to become, to flourish and to be maintained. A gardener chooses plants and plants them, taking the special characteristics of the garden in consideration, such as its physical dimensions, availability of water, light, oxygen, nutrients, and other plants. The gardener also prunes and reorders yet does this in response to how the garden develops and becomes, with the intention to make it flourish. The steward is particularly keen on maintaining equilibrium and facilitating emergence, and observes, listens, senses, feels, and facilitates through occasional provisions, interventions, planting and pruning. The teacher of the knowledge ecosystem is basically doing the same. Occasionally he or she plants and prunes as in traditional teaching and correcting. Yet most of the time he or she observes, listens, senses and feels, and based on that facilitates: stimulates emergence, creates space and provides where so is desired. All with the intention of stimulating a fruitful dialogue between the multiple knowledge elements of the system. It is this metaphor that, I think, is the best starting point to create education for transdisciplinary hermeneutical knowing, incorporating the seven steps previously mentioned in the metaphor.

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the South), transdisciplinary hermeneutics, reflective practice, emotional intelligence and embodied cognition and mindfulness. The past 15 years he has been working on the development of the field of Art and Sustainability that allows him to integrate several of the above-mentioned themes.

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# CHAPTER **17**

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## Transdisciplinary Trans-Sector Integration in Education: Convergence

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*This chapter examines A-STEM-H (Art & Science, Technology, Engineering, Math and Humanities) Transdisciplinary Domain – teaches students new skills aimed at creativity, innovation, and working across knowledge fields; offers an approach that synthesizes methodologies from multiple fields; teaches the ability to collaborate across multiple spheres of knowledge and practice; prepares students to design, develop, and deliver a system that qualifies a student to be workforce ready.*

*This chapter also proposes a unique transdisciplinary Ph.D. program and curriculum representing eight main sector activities selected from primary, secondary and tertiary (service) sectors in the United States which impacts the global economy.*

**Keywords:** A-STEM-H, transdisciplinary domain, trans-sector, transdisciplinary curriculum.

### 17.1 Introduction

Transdisciplinarity can be defined as the practice of acquiring new knowledge through education, research, design, and production with a broad emphasis on complex problem solving. The goal of transdisciplinary practice is to improve students' understanding of complex issues by extracting the valuable aspects of typical academic disciplines and thereby generating both a more integrative

and universal solution to support an issue of importance to society (Ertas et al., [1]).

An interdisciplinary (ID) methodology has been defined as “two or more disciplines which combine their expertise to jointly address an area of common concern” (Ertas et al., [2], Devlin, [3]). “Interdisciplinary approaches integrate separate disciplinary data, methods, tools, concepts, and theories in order to create a holistic view or common understanding of complex issues whereas transdisciplinary approaches are comprehensive frameworks that transcend the narrow scope of disciplinary world views through an overarching synthesis (Klein, [4])”. Transdisciplinary (TD) research includes cooperation within the scientific community and a debate between research and society at large. TD research therefore transgresses boundaries among scientific disciplines and between science and other fields and includes deliberation about facts, practices and values (Hadorn et al., [5]).

“Convergence: facilitating transdisciplinary integration of life sciences, physical sciences, engineering, and beyond is an approach to problem solving that cuts across disciplinary boundaries. It integrates knowledge, tools, and ways of thinking from life and health sciences, physical, mathematical, and computational sciences, engineering disciplines, and beyond to form a comprehensive synthetic framework for tackling scientific and societal challenges that exist at the interfaces of multiple fields. By merging these diverse areas of expertise in a network of partnerships, convergence stimulates innovation from basic science discovery to translational application. It provides fertile ground for new collaborations that engage stakeholders and partners not only from academia, but also from national laboratories, industry, clinical settings, and funding bodies. (National Research Council of the National Academies, [6])”

The expected results of TD research and education are: emphasis on teamwork; bringing together non-academic experts and academic researchers from diverse disciplines; developing and sharing of concepts, methodologies, processes, and tools; all to create fresh, stimulating ideas that expand the boundaries of possibilities. The TD approach teaches students to seek collaboration outside the bounds of their professional experience to make new discoveries, explore different perspectives, express and exchange ideas, and gain new insights.

## **17.2 Need for Transdisciplinary Graduate Education**

“If the world of working and living relies on collaboration, creativity, definition and framing of problems and if it requires dealing with uncertainty, change, and intelligence that is distributed across

cultures, disciplines, and tools—then graduate programs should foster transdisciplinary competencies that prepare students for having meaningful and productive lives in such a world,” (Derry and Fischer, [7]).

Graduate education today is experiencing a period of profound transformation. Phenomena such as the information technology revolution and globalization (National-Research-Council, [8]), globalization (Friedman, [9]), growing trends to outsource high-level cognitive tasks (Aspray, Mayadas, & Vardi, [10]; Levy & Murnane, [11]), and the need to contribute successfully in diverse collaborative organizations addressing today’s complex world problems (Brown & Duguid, [12]) are changing goals of the graduate education (Derry and Fischer, [7]).

Requirements have changed over the years for Ph.D. graduates to enter work settings requiring collaboration with experts from multiple fields, pursue several career paths tackling different problems, and to interact and work with people of diverse backgrounds including experts those from outside academe (Derry and Fischer [7], Golde, [13]; Panofsky & Rhoten, [14]). Such changes create new educational requirements: graduate students would greatly enhance their skills and employment opportunities if they were able to master TD competencies before they go on to employment.

Transdisciplinary can help in making creativity more evident in the teaching and research activities of universities (McWilliam et al., [15]). “The increasing understanding of the importance of technological innovation to economic competitiveness is challenging a new pressure for engineering education and research at the extremely difficult technical, medical, social, and cultural problems. Scarcity of knowledge base to solve these problems is becoming more and more predominant. Therefore, engineering education must produce highly qualified, well-trained engineers who can interface with other sectors of society to address complex problems require many activities which cross discipline boundaries,” (Ertas et al., [16]).

Several academic institutions in globe already have set up programs to support TD research and education. Cronin stated that “There is a need for transdisciplinary research (TR) when knowledge about a societally relevant problem field is uncertain, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by problems and involved in dealing with them. TR deals with problem fields in such a way that it can: a) grasp the complexity of problems, b) take into account the diversity of life world and scientific perceptions of problems, c) link abstract and case specific knowledge and d) constitute knowledge and practices that promote what is conceived to be the common good.” (Cronin, [17]).

Since 2005, Transdisciplinary Studies Program at Claremont Graduate University have offered over 80 transdisciplinary courses. These courses introduce students to the practices of transdisciplinary study and foster collaborations across disciplines and schools that would not necessarily occur in traditional single-discipline courses [18].

The Center Leo Apostel (CLEA) was created in 1995 as a transdisciplinary research department. The center's goal is the development of world views that integrate the results of different scientific and cultural disciplines. Crossing the boundaries of natural sciences, the social sciences, and humanities for knowledge generation is the main objective of CLEA [19].

Network for Transdisciplinary Research (td-net) was created in 2000 by the Swiss Academic Society for Environmental Research and Ecology (SAGUF) and taken over by the Swiss Academy of Sciences (SCNAT) in 2003. Since 2008, the td-net for transdisciplinary research has been a project of the Swiss Academies of Arts and Sciences.

The National Cancer Institute (NCI) was authorized by NIH as the first institute for transdisciplinary approach to health research. Its Transdisciplinary Tobacco Use Research Center (TTURC) initiative was initiated in 1999 and three center programs followed in the early 2000s: the Centers of Excellence in Cancer Communication (CECCR) and Centers for Population Health and Health Disparities (CPHHD) in 2003 and Transdisciplinary Research in Energetics and Cancer (TREC) centers in 2004. These research centers across the United States are developing and translating scientific knowledge and discoveries into new treatments for cancer patients.

Recently, a 13.5 million dollar grant has been awarded jointly to the University of Minnesota and the University of Alabama, Birmingham, to initiate the National Transdisciplinary Collaborative Center for African American Men's Health (NTCC). This funding is provided by the National Institutes for Health's National Institute on Minority Health and Health Disparities. The grant started on July 1, 2013, and will fund five years of activity for the center [20].

A report presented to the Texas Higher Education Coordinating Board by the Graduate Education Advisory Committee (GEAC), in July 2, 2009 states that "the research and education at Texas universities must continue to work at the transdisciplinary frontiers of knowledge, and that work will require collaboration throughout the state, not only among various disciplines, researchers, and institutions but also with local businesses and governments" Three critical success factors for global Competitiveness out of eleven were related to transdisciplinary [21]:

- Number of interdisciplinary or transdisciplinary funded research collaborations within a university,
- Number of interdisciplinary or transdisciplinary funded research collaborations among universities, and
- Number of new transdisciplinary programs

Challenging technical, medical, social and cultural issues and the complex nature of community and world problems has intensified the need to provide students with an education that enables them to work on a wide range of topics emphasizing on collaboration, cross-discipline team based research and

development of habits for life-long learning. To meet this need, in 2007, after graduating 126 MS students; upon Raytheon's management request very successful Transdisciplinary Master's program was expanded to a Transdisciplinary PhD program (Ertas et. al., [1]) . So far, more than 50 Ph.D. students have enrolled to this program.

Transdisciplinary research and education could initiate many breakthroughs that improve lives and strengthen the economy, however cultural and institutional barriers interfere with its development. In spite of these difficulties, we have established a unique and vital on-campus Transdisciplinary PhD Program focus on a Design, Process, and Systems track that is offered by the Mechanical Engineering Department at Texas Tech University. A systems approach of this Ph.D. program considers research projects on Art & Science, Technology, Engineering, Math and Humanities (A-STEM-H).

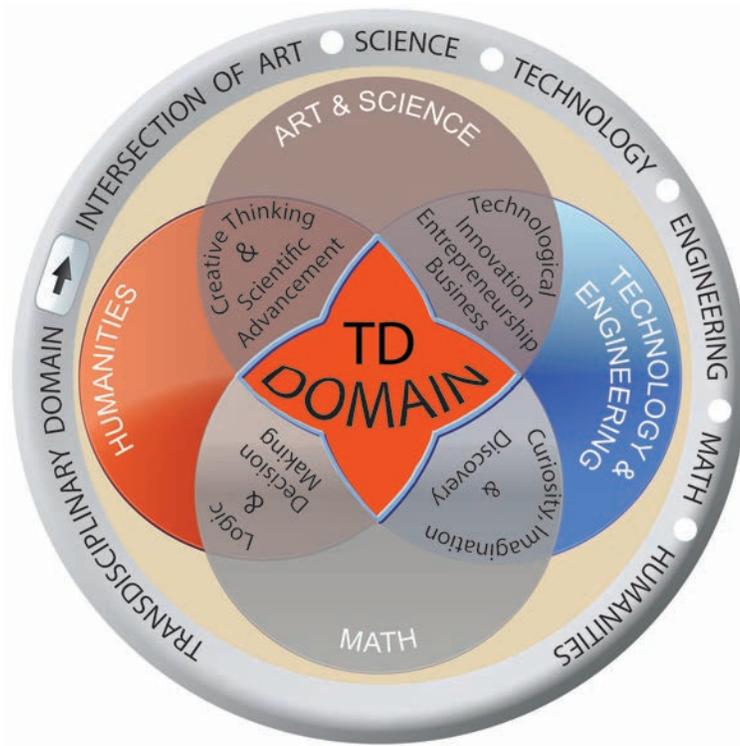
Many other universities have developed transdisciplinary studies around the world. Some of them are: Graduate School Frontier Science-The University of Tokyo, The Graduate School of the University of North Carolina at Chapel Hill, University of Wisconsin-Madison, Burnham Institute for Medical Research, New York University, The Virginia Bioinformatic Institute at Virginia Tech, Salve Regina University, Woodbury University, University of Calgary Transdisciplinary Colleg, Brown University, University of Colorado-Boulder, CINII- National Institute of Informatics, University of Southern Queensland, University of California, San Francisco, Transdisciplinary Educational Achievements in Romania, The University of Vermont, Arizona State University School of Sustainability, University of Stellenbosch University and Korea Institute for Advanced Study (ATLAS, [22]).

### 17.2.1 A-STEM-H Transdisciplinary Domain

Figure 17.1 describes the attempt to integrate arts and humanities into STEM education. A-STEM-H is not only just science, technology, engineering, and math education – It is a Transdisciplinary applied approach that is linked with real-world problem based learning. Connections between STEM and sister disciplines such as art and humanities occur at the boundary of the Transdisciplinary domain – intersection of art and science, technology, engineering, math and humanities. The six discrete disciplines are not anymore separate but “interconnected” through an acronym, A-STEM-H. Interconnection between disciplines goes beyond integration. A-STEM-H is a system of interconnected disciplines without boundaries within the TD domain which creates a cohesive teaching and learning paradigm. Transdisciplinary A-STEM-H integrates knowledge, tools, methods, and cognitive thinking skills from a wide diversity of fields to form an inclusive framework to solve challenging complex contemporary social issues that exist at the interfaces of multiple disciplines.

Using system analogies, we can conclude for important characteristics of A-STEM-H as:

- All six disciplines of A-STEM-H interact with and rely on one another



**Figure 17.1:** A-STEM-H Transdisciplinary Domain.

simply by the fact that they occupy the same Transdisciplinary Domain – Interconnectivity.

- All six disciplines of A-STEM-H, which interact with one another within the TD Domain and cannot be analyzed as transdisciplinarity if considered alone.
- A-STEM-H provides an educational capability that is greater than the sum of the contributing disciplines.

Unique contributions of the humanities to A-STEM-H education may be considered as follows (Donnelly, [23]).

- an appeal to an autonomous self with the right and capacity to make independent decisions and interpretations;
- indeterminacy in the subject matter of these decisions and interpretations;
- a focus on meaning, in the context of human responses, actions, and relationships, and particularly on the ethical, aesthetic, and purposive;

and

- the possibility of cohesion in standards of decisions and interpretation.

The arts play an important role in science and engineering and hold the knowledge and skills a person needs to participate actively in civic life. The arts can provide ways for both scientists and engineers to broaden their understanding of concepts from diverse disciplines and generate creative, innovative solutions to unstructured problems. In particular, the arts can help people develop skills such as visual thinking; recognizing and forming patterns; modeling; getting a “feel” for systems; and the manipulative skills learned by using tools, pens, and brushes are all demonstrably valuable for developing STEM abilities (Root-Bernstein, [24]). The art provides students with problem-solving skills, innovative mindsets, communicative attitudes and motivation. There have been experimental studies which indicate that intense exposure to art develops superior spatial-visual coordination and other basic skills (Shuster, [25]).

Business leaders and economists emphasizing that both the arts and humanities provide the creative and critical thinking skills workers need in a new technology driven economy that emphasizes multidisciplinary pursuits such as biotechnology, nanotechnology, green energy, clean technologies, and digital media (Root-Bernstein, [243]).

### 17.3 Proposed Transdisciplinary Graduate Education

#### *Trans-sector Innovation for Sustainable Development*

The major factor of the *trans-sector* concept is that governments together with industries should develop policies and strategies that will bring various sectors together to tackle and understand the current and future impact of key disruptions on employment levels, skill sets and recruitment patterns in different industrial sectors.

“Given the complexity of the change management needed, businesses will need to realize that collaboration on talent issues, rather than competition, is no longer a nice-to-have but rather a necessary strategy. Multi-sector partnerships and collaboration, when they leverage the expertise of each partner in a complementary manner, are indispensable components of implementing scalable solutions to jobs and skills challenges. There is thus a need for bolder leadership and strategic action within companies and within and across industries, including partnerships with public institutions and the education... These efforts will need to be complemented by policy reform on the part of governments.” (World Economic Forum, 2016 [26])

We propose a unique transdisciplinary Ph.D. program and curriculum representing eight main sector activities selected from primary, secondary and tertiary (service) sectors in the United States which impacts the global economy. Namely; healthcare, technology (information technology, nanotechnology, biotechnology, 3D printing, robotics, artificial intelligence etc.) finance & business, manufacturing, energy, transportation, defense and agriculture. There is an inter-relationship among the products provided by all these sectors. In other words, one sector's products are interrelated with other sectors' products. For example, efficiency of manufacturing products depends on many other sectors' products. "A number of drivers of change will have severe impact within specific industries. For example, new energy supplies and technologies will have a particular impact on the Energy, Basic and Infrastructure and Mobility industries. Processing power and Big Data will have an especially strong impact on Information and Communication Technology, Financial Services and Professional Services" (World Economic Forum, [26]). Naturally, these sectors should start working together towards a common integrated solution of the complex problems and issues facing mankind in the 21st century. The main challenge will be integrating this whole concept into the transdisciplinary advanced education. Not only the physical integration of trans-knowledge into a transdisciplinary advanced education plays a role, but also the integration of different sectors that are not currently working together is challenging. The real question is then: how integration of complexity and effort can be minimized in building bridges between various sectors? This requires a greater focus on broad customary *digital education* (instructional practice that effectively uses technology to strengthen a student's learning experience) integrating A-STEM-H areas and the development of inherently transdisciplinary education processes and curriculum (Ertas, [27]).

Integration of functions especially that are syntactic in nature, provided by different sectors, is very slow and inefficient at this time – trans-sector *interoperability*: exchange of information of two or more sectors and use of the information that has been exchanged is problematic. Minimization of the integration complexity effort is the key issue for the success of trans-sector innovation. Semantic web service is one of the recent state-of-the-art developments which can be used in trans-sectors innovation for minimizing the integration effort (Bastiaansen and Baken,[28]).

The proposed program aims to provide a semantic problem solving platform (SPSP) that facilitates personalizable, transdisciplinary education where problem solving resources can be easily connected based on semantics in order to solve problems. The connection between students and resources can be made via [29]:

1. semantic interfaces, which interpret and understand problems;
2. semantic analysis, which analyzes the resources available; and
3. semantic synthesis, which integrates multiple resources into a solution.

Unification and integration of knowledge from sectors through transdisciplinary educational program is an ideal dream. Trans-sector knowledge and tools creation and integration into a transdisciplinary advanced education will be the main objective of this new program. Through this project we will bring up some promising trans-sector innovation ideas and provide new concepts for trans-sector innovation framework. Social, economic and environmental dimensions of the transdisciplinary sustainable development will be augmented in the curriculum.

The idea of trans-sector innovation brings stakeholders together from academia, industry and government to solve complex problems by relying on merged perspectives. The major element of the trans-sector concept is that governments and industries need to develop policies and strategies that will bring diverse sectors together to tackle some of the complex and discouraging issues that are exist in today's world. By bringing the diverse sectors together, common vexing problems will be solved as different participants react to different aspects of the problem in different ways, but all still with the same direction or goal in mind (Budde, [26]). This type of collaboration can spawn innovative solutions that could have impact on the solution of complex problems.

### 17.3.1 Proposed Transdisciplinary Ph.D. Curriculum

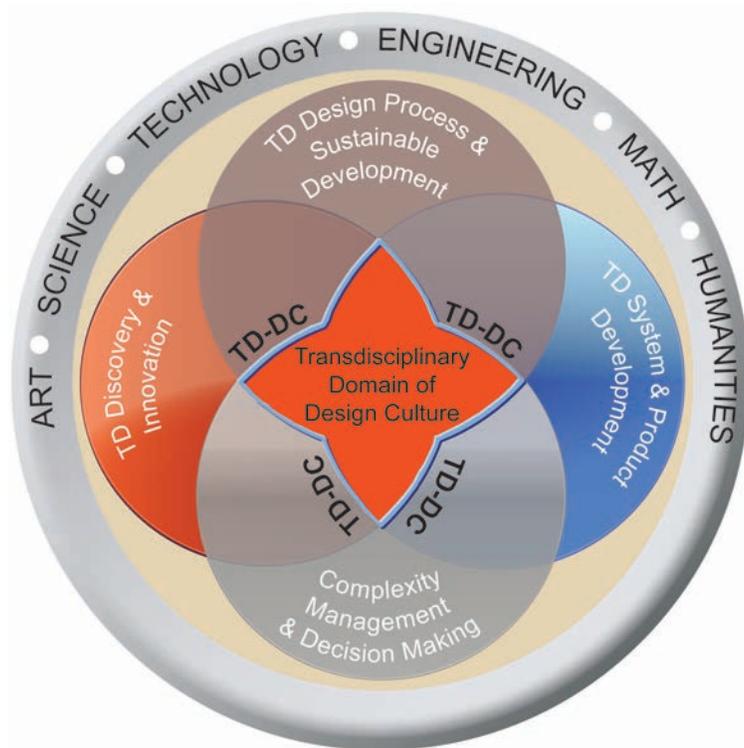
Students entering transdisciplinary Ph.D. program must have already earned a MS degree and will take following core, supplementary and complementary courses.

#### Transdisciplinary Core Courses

*Educate the next generation with TD skills and create a world-class workforce.*

There is a need for Transdisciplinary Design Culture (TD - DC) in higher education which can be built on the existing foundation that is provided by A-STEM-H. As shown in Figure 17.2, those four TD core courses should be in perfect harmony – they should be interconnected for the mutual exchange of knowledge. TD core courses are designed in a way that the specific subjects within and among the TD core courses can be easily synchronized and complement each other. Then, we can assume that interconnectivity exists and TD core courses are connected without boundaries within the TD–DC domain. This process provides a knowledge capability that is greater than the sum of the contributing core courses (Ertas et. al. [1]).

The content of the four core TD courses will include information and knowledge common to multiple disciplines and also aforementioned eight main sector activities. The four synchronized TD core courses will provide the students with a foundation in the TD skills required to identify, frame, and address important practical problems that cut across disciplinary boundaries. The proposed four TD core courses will support collaborative research based TD



**Figure 17.2:** Domain of Transdisciplinary Design Culture (Ertas et. al. [1]).

program which will be highly multidisciplinary and will represent A-STEM-H (see Figure 17.2). Contents of the four proposed TD core courses are:

1. **Complexity Management & Decision Making:** A practical foundation for complexity management (related to human behavior, societal systems, economic systems, and environmental systems) will be presented that enables a system's complexity to be evaluated against its functions and qualitative factors, such as social mores and human values. The course will cover a) definitions and characteristics of complexity; b) understanding complexity: thought and behavior; c) modeling of complex systems; d) tools and methods for managing complex systems; e) strategies for reducing social complexity; f) complexity and structure; g) management of knowledge and integration; h) managing complexity through systems design; and i) Interactive Management (IM).
2. **Transdisciplinary Design Process & Sustainable Development:** Fundamentals of TD design and research processes and applications, models to address trans-sector digital interoperability, TD assessment

and methodology development to guide research, policy and action towards sustainability will be covered. Students will learn broad research skills and knowledge in strategies for sustainable integration, sustainable resource use and management, environmental conflict resolution, policy formulation and decision-making. Interoperability framework tool (ATHENA), Interpretive Structural Modeling (ISM) tool to decompose complexity due to integration will be introduced. Rural and urban sustainability, ecological sustainability, the interconnectivity of environment, economy and society will also be covered.

3. **Transdisciplinary Discovery and Innovation:** The focus of this course is to enable the students to work jointly with others across disciplines. This course covers: generic design; idea generation and management; brain-writing pool and idea structuring; tradeoff analysis methodology (TAM); collaborative activities, practice and research ethics; TD research process using a systems approach; impact of social issues on design; TD case studies; the role of experts in TD research processes; the use of Big Data to address world's most pressing societal, global, business, and educational complex issues will also be covered.
4. **Transdisciplinary System and Product Development:** This course teaches system and product development methods, techniques and tools so that students can have a big-picture view of the whole system/product lifecycle and can use systematic approaches to design and develop products and systems. Risk assessment, and how to deal with uncertainties will also be covered.

### **Supplementary Courses**

1. **Biomimetic Systems Design:** Biomimetic systems design is the use of biological models to solve analogous engineering problems. Biological systems can provide stimulation for many various design objectives, including adaptability to changing environments, optimization, sustainability, repair, risk analysis and remanufacture. Systematic methods and processes are presented for engineers to access biological knowledge, identify relevant biological phenomena, comprehend material in the biological disciplines, and apply analogical reasoning to create new knowledge.

The objectives of this course are provide students with 1) an introduction to a broad range of biological systems; 2) a foundation in the application of analogical reasoning in transdisciplinary conceptual design of products, processes, and systems; 3) a generalized methodology for identifying and applying biological phenomena to engineering problems; and 4) an understanding of the application of computational tools (cyberinfrastructure) to search another discipline, locate phenomena, and identify relevance of phenomena.

2. **Uncertainty Analysis in System Design:** Uncertainty occurs in

most engineering systems. Uncertainty may arise from variability inherent in systems and from incompleteness of statistical data. Techniques will be developed that can be used to quantify uncertainty and risk inherent in engineering systems. These techniques will be applied to examples that include: mechanical engineering, bioengineering, electrical engineering, and computer engineering, etc.

3. **Technological Innovation, Entrepreneurship & Business:** Students will be prepared for managing innovation and entrepreneurship, how to use tools and techniques needed to manage and exploit technological investments and opportunities for technical innovations that can lead to viable commercial products and profitable businesses.
4. **Complex Problem Case Studies:** In this course, students will be allowed (a) to develop their own research-based, open-ended complex case studies related to uncertain events such as broad range of Global risks – when they occur, these events can cause significant negative impact on the state of the world.(b) Propose solutions, employing critical and creative thinking skills.

Some of the likelihood of Global risks are: health issues (e.g. rapid and massive spread of infectious diseases etc.), energy price shock to the global economy, unmanageable inflation, extreme weather events (e.g. floods, storms, etc.), failure of climate-change adaptation, major natural catastrophes (e.g. earthquake, tsunami, volcanic eruption, geomagnetic storms), food crises, water crises, large-scale cyber attacks, breakdown of critical information infrastructure and networks, massive and widespread misuse of technologies (e.g. 3D printing, artificial intelligence, geo-engineering, synthetic biology, etc.), climate change, environmental degradation, urbanization, rising income disparity, weakening of international governance [30]

Students will be working in research teams to give them the opportunity to develop and practice the collaborative, interpersonal and organizational skills that are crucial to strengthen the students' teamwork and leadership abilities.

### **Complementary Courses**

Students are required to take one (1) complementary course chosen from any discipline – in art & science, humanities and engineering as part of their coursework.

## **17.4 Discussions**

As shown in Figure 17.1, sub-domain of A-STEM-H created at the intersection of the two domains (art & science and technology & engineering) that have the greatest value to prepare students for effective transitions into technological

innovation, entrepreneurship and business. Scientists and engineers play an important role in building the 21st century science and technology enterprises that will create solutions and jobs essential for solving large complex trans-disciplinary problems faced by the society. Entrepreneurship using innovative business enterprises adds to the secure development of social, economic, and environmental concerns related to human quality of life.

Sub-domain created by technology-engineering-math adds value and knowledge for features technological invention and discovery – requires creativity and imagination. There is almost no creativity without imagination. Advances in the mathematical sciences creating new Technologies, discoveries and transforming industries.

*“Imagination has brought mankind through the Dark Ages to its present state of civilization. Imagination led Columbus to discover America. Imagination led Franklin to discover electricity. Imagination has given us the steam engine, the telephone, the talking-machine and the automobile, for these things had to be dreamed of before they became realities. So I believe that dreams – day dreams, you know, with your eyes wide open and your brain-machinery whizzing – are likely to lead to the betterment of the world. The imaginative child will become the imaginative man or woman most apt to create, to invent, and therefore to foster civilization.” – L. Frank Baum [31].*

Sub-domain of A-STEM-H created at the intersection of the two domains (Math and Humanities) is the central to the body of prescriptive knowledge about decision making – a sophisticated mathematical model of choice that lies at the foundation of most contemporary research methods and techniques. Problem solving and decision making is mainly concerned with how people reduce problems down to size – how they apply approximate, heuristic techniques to handle complexity that cannot be handled exactly. The increasing understanding that managing with complexity is essential to human decision making and strongly influences the directions of research – a new body of mathematical theory developing around the topic of computational complexity is establishing a powerful new computational tool [32].

The last sub-domain is the creative thinking and scientific advancement. Science plays an important role for scientific advancement and creating innovative technologies. As technological innovation, globalization, and international competitiveness continue to challenge business organizations, creative thinking skills and the ability to solve vexing problems have become necessary for students.

A-STEM-H transdisciplinary domain teaches students new skills aimed at creativity, innovation, and working across knowledge fields; offers an approach that synthesizes methodologies from multiple fields; teaches the ability to collaborate across multiple spheres of knowledge and practice; prepares students

	Energy	Healthcare	Technology	Agriculture	Manufacturing	Transportation	Finance & Business	Defense
	1	2	3	4	5	6	7	8
Energy 1	\	V	X	X	V	V	O	V
Healthcare 2		\	A	A	A	O	O	O
Technology 3			\	V	V	V	A	V
Agriculture 4				\	A	A	A	O
Manufacturing 5					\	V	A	V
Transportation 6						\	A	V
Finance & Business 7							\	V
Defense 8								\

**Figure 17.3:** Structural self-interaction matrix (SSIM) for trans-sector activities.

to design, develop, and deliver a system that qualifies a student to be workforce ready.

Interpretive Structural Modeling (ISM), a methodology for dealing with complexity is used to decompose the complex interactions of trans-sectors (Ertas, et al., [33]). As shown in Figure 17.3, using expert opinions, Structural Self-Interaction Matrix (SSIM) of contextual relationship of eight trans-sectors was established. The following four symbols were used to describe the interactions between the trans-sectors in the SSIM.

- The letter V stands for events when the row element influences the column element.
- The letter A stands for events when the column element influences the row element.
- The letter X stands for events when the row and column elements influence each other.
- The letter O stands for events when there is no relationship between the row and column elements.

In developing structural self-Interaction matrix, if the relationship between factors is weak, it is assumed that there is no relationship between factors.

		1	2	3	4	5	6	7	8	Driving power
$R_f =$	Energy 1	1	1	1	1	1	1	0	1	7
	Healthcare 2	0	1	0	0	0	0	0	0	1
	Technology 3	1	1	1	1	1	1	0	1	7
	Agriculture 4	1	1	1	1	1	1	0	1	7
	Manufacturing 5	1	1	0	1	1	1	0	1	6
	Transportation 6	1	1	0	1	0	1	0	1	5
	Finance & Business 7	1	1	1	1	1	1	1	1	8
	Defense 8	0	0	0	0	0	0	0	1	1
	Dependence	6	7	4	6	5	6	1	7	$\Sigma = 42$

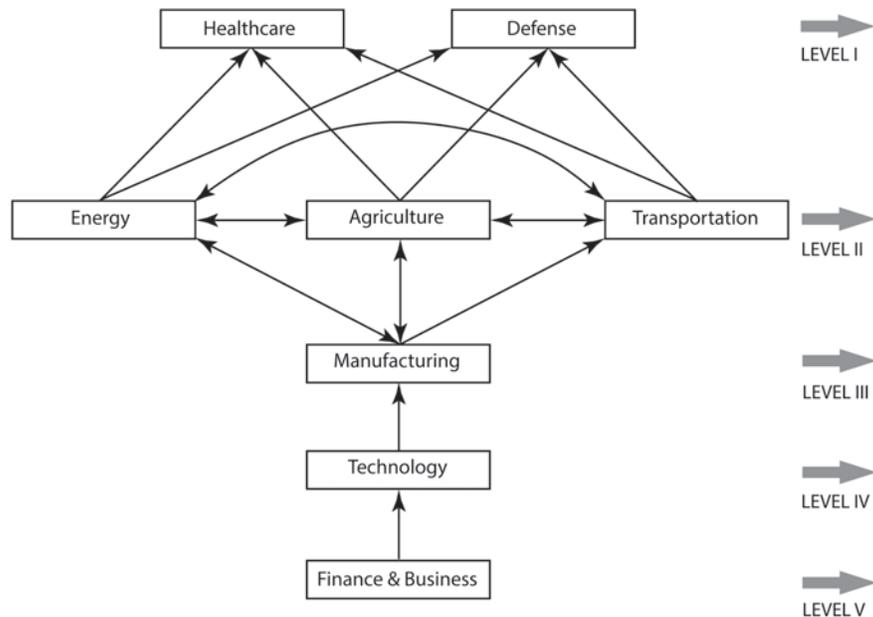
Figure 17.4: Final reachability matrix.

Then the adjacency matrix, was developed by transforming SSIM into a binary matrix by substituting V, A, X, and O by 1 and 0 per the schema described above in the matrix that reflects the directed relationships between the elements (Ertas, et al., [33]). Then, final reachability matrix,  $R_f$  with transitivity which includes driving power and dependence of each trans-sector was obtained (see Figure 17.4). Summation of ones in the corresponding rows gives the driving power and the summation of ones in the corresponding columns gives the dependence. Level partitioning along with the final reachability matrix helps to build the diagraph (directed graphs) for trans-sector activities shown in Figure 17.5. This figure depicts visually the direct and indirect relationships between trans-sector activities and shows the five level decompositions of the complex inter-relationship.

Since large number of lines enter and leave sectors of energy (1), agriculture (4), transportation (6) and manufacturing (5) shown in Figure 17.5, they are the most critical and important sectors among others. These four sectors not only affect but also they are affected by the other sector activities – they are linkage sectors (see Figure 17.6). Thus, trans-sector knowledge and tools creation and integration into a transdisciplinary graduate education should be considered for comprehensive integrative curriculum design.

As shown in Figure 17.6, all eight trans-sector activities have been classified into four categories (MICMAC analysis). The purpose of MICMAC analysis is to arrange the factors with respect to their driving power and dependence in four clusters. Cluster I includes autonomous factors. As seen from the figure, they have low driving power and low dependence, hence they can be eliminated from consideration. For this case, no sector has been identified as an autonomous factor. This indicates that there is no disconnected sector in trans-sector activities.

Cluster II includes dependent sectors activities that have low driving power and high dependence. As seen from Figure 17.6, sectors healthcare (2) and



**Figure 17.5:** Directed graph for trans-sector activities.

defense (8) have a smaller guidance power but it is extremely dependent to the other sector activities and don't affect other sector activities. However, they are also very important sectors to be considered for the curriculum development as they are positioned at the top of the hierarchy (see Figure 17.5).

Cluster IV includes independent sectors of finance & business (7) and technology (3) with a strong drive power but very weak dependence. These two sectors are the key driver for the curriculum development as they impact on the other sectors activities but not necessarily affected by the other sector activities. Finance & business sector is the source sector since it has only outgoing path.

## 17.5 Conclusion

The Fourth Industrial Revolution, which includes developments in previously disjointed fields such as artificial intelligence and machine-learning, robotics, nanotechnology, 3-D printing, and genetics and biotechnology, will cause widespread disruption not only to business models but also to labour markets over the next five years, with enormous change predicted in the skill sets needed to thrive in the new landscape [26].

“The impact of technological, demographic and socio-economic disruptions on business models will be felt in transformations to the

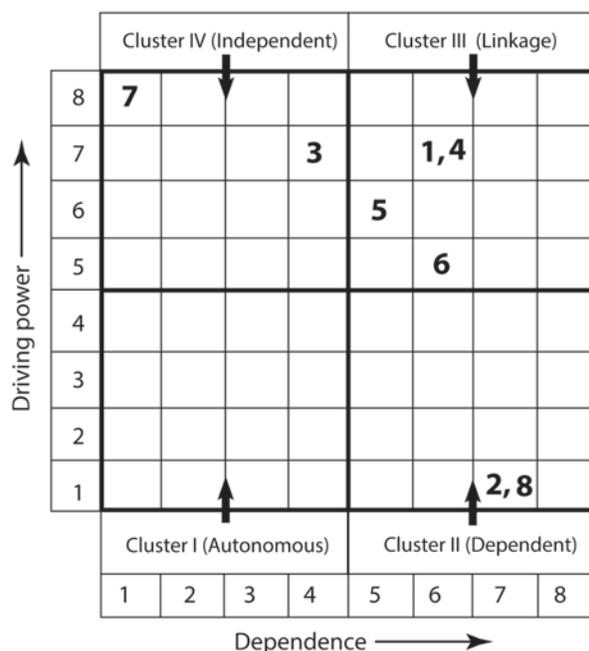


Figure 17.6: MICMAC Analysis for trans-sector activities.

employment landscape and skills requirements, resulting in substantial challenges for recruiting, training and managing talent.” (World Economic Forum, 2016 [26])

During previous industrial revolutions, it often took decades to build the training systems and labour market institutions needed to develop major new skill sets on a large scale. Given the upcoming pace and scale of disruption brought about by the Fourth Industrial Revolution, however, this is simply not be an option. Without targeted action today to manage the near-term transition and build a workforce with future proof skills, governments will have to cope with ever-growing unemployment and inequality, and businesses with a shrinking consumer base. Moreover, these efforts are necessary not just to mitigate the risks of the profound shifts underway but also to capitalize on the opportunities presented by the Fourth Industrial Revolution. The talent to manage, shape and lead the changes underway will be in short supply unless we take action today to develop it.

For a talent revolution to take place, governments and businesses will need to profoundly change their approach to education, skills and employment, and their approach to working with each other. Businesses will need to put talent development and future workforce strategy front and centre to their growth. Firms can no longer be passive consumers of ready-made human capital. They

require a new mindset to meet their talent needs and to optimize social outcomes. Governments will need to re-consider fundamentally the education models of today. As the issue becomes more urgent, governments will need to show bolder leadership in putting through the curricula and labour market regulation changes that are already decades overdue in some economies.

In conclusion, this chapter motivates the need for a new transdisciplinary graduate curriculum development. The author proposes trans-sector knowledge and tools creation and integration into a transdisciplinary graduate education. Trans-sector advocacy is important in the education sector helping to support the process of unifying common shared methods and tools used by major sectors impacting the global economy. Students educated through proposed transdisciplinary education will develop fast transition and adaptation time in different sectors mentioned in this chapter.

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# CHAPTER 18

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## Cosmodern Education for a Sustainable Development: a Transdisciplinary and Biomimetic Approach from the Big History

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*The objective of this chapter is to study the co-evolutionary processes that life has developed over billions of years in the context of “Big History”. The main intention is to identify their operational principles and strategies, in order to promote sustainable and bio-mimetic alternatives for the achievement of the “Sustainable Development Goals” (SDG). This is a qualitative, exploratory, descriptive, and analytical research that includes, unifies, and integrates the history of the universe, the solar system, Earth, and human being history. For the development of this “ecology of knowledge”, transdisciplinary methodology is combined with the Big History theoretical model. The most important observations show that all forms of life are developing sustainable co-evolutionary strategies in nature since life’s first appearance about 3,8 billion years ago. To help in the achievement of the SDG, the research also focuses on human training to reduce ecological and social footprint. As a result, emotional, spiritual, and ecological literacy is required to feel-think-act in harmony with nature. In conclusion, this biomimetic and transdisciplinary research proposes some recommendations to prevent future scenarios where the chronic shortage of natural resources impedes dignified human development and proliferation of life.*

**Keywords:** Cosmodernity, biomimicry, transdisciplinary, big history, coevolution, complexity, spirituality, emotional intelligence, sustainable development goals.

## 18.1 Sustainable Development Goals: an Introduction

Sustainable development has gained momentum since the Member States of the United Nations committed to the Sustainable Development Goals (SDGs) for the year 2030. The final declaration signed by world leaders is known as “Transforming our World: The 2030 Agenda for Sustainable Development” (United Nations, 2015), and it includes climate change, conservation of terrestrial ecosystems, seas and oceans, as well as other systemic and global goals on health, gender, poverty, and education. In sum, the 17 SDGs and 169 targets recognize the socio-ecological problems that characterize the current global civilization beyond their national borders. Hence the need to transgress the current paradigm with the new approach that Big History gives us, because it represents an epistemic tool that conceived the interrelationships of the human condition in its cosmic and earthly context. This is a new transdisciplinary organization of knowledge that allows us to include natural ecosystems and human cultural systems in the same co-evolutionary historical process.

The Big History helps us to identify and recognize the sustainable strategies that work in nature to inspire us bio-mimetically in solving human problems (i.e. social, economic, technological, engineering, etc.). The continued exploitation of materials and energy resources of the Earth by the models of production and consumption has caused a great ecological and social footprint that has been disclosed as unsustainable. A society that walks towards a sustainable development must learn to reduce their ecological destruction, reusing and recycling materials already built. Sustainable development is a dynamic process that requires a “*glocal*” vision, because the global progress is an emergency of planetary system which thrives on multiple local progress advancing through systemic mechanics (synergies, feedbacks, etc.) that inter-retro-act with each other, influencing, conditioning, and modifying the different context of world citizenship. According to Robertson [1], the term “glocal” is a neologism where globalization does not imply an annulment of the local, but an inclusion, presence, and meeting of and with local cultures. We must focus our attention on the paradigmatic horizon of SDG in a planetary scale, engendering a world where “other worlds are possible”. This implies a transcultural recognition of cosmic structures and phenomena that paradigmatically transcend the human condition, aligned with the “*Cosmic Education*” of the pedagogical method of Maria Montessori [2].

## 18.2 Transdisciplinary Methodology: Linking Education with Sustainability

The idea of interconnection between human beings and other life forms leads us to revise the concept of development through transdisciplinary study. Life has developed co-evolutionary processes since their appearance on Earth some

3.8 billion years ago. The “cosmic miracle of life” is a transdisciplinary challenge we must integrate to safeguard all biodiversity that coevolves in Gaia<sup>1</sup>. This essay has been written from the theoretical framework of the “Big History” coined by historian David Christian [3] and theoretically developed by Fred Spier [4], along the methodology proposed by nuclear physicist Basarab Nicolescu [5]: levels of reality, logic of the middle hidden, and complexity. This theoretical and methodological symbiosis represents an epistemological approach that understands the human beings as an integral part of autopoietic cosmic totality, housing the bioethical imperative to develop a culture of peace to meet the SDG [6]. In addition, this synergy also aims to produce both new biomimetic knowledge and technical innovations. According to the economist and educator Sue McGregor [7: 63], “transdisciplinary problem solving from a biomimicry perspective means recognizing organic patterns and natural connections, understanding the causes and effects of competing and interrelated components, and then making appropriate modifications.” The nature of sustainability from a biomimicry perspective reflects the very essence of transdisciplinary methodology and the Big History theoretical framework. The fit between those two approaches is elegant, ripe with hope and potentialities.

According to the “complex thinking” promoted by sociologist Edgar Morin in his book *The Seven Complex Lessons in Education for the Future*, - written in 1999 to promote UNESCO’s Transdisciplinary Project *Educating for a Sustainable Future*-, education is an essential epistemic tool to transform our world-society. In this visionary work, Morin affirms, “teaching the human condition means teaching the cosmic, physical, and earthly condition of the individual-society-species” [8: 21-23]. Since these intellectual horizons, all education pretending to be universal must take into account the different levels of epistemological and ontological reality that constitute the multidimensional identity of the individual-society-species: as *individual* in a local and specific community; as citizen of a determinate *society* belonging to a particular State/Nation; and as same cosmo-bio-genetic *species* in constant process of evolution. A human identity opened to the infinite diversity of global citizenship in its own unity as species. At the same way that own ontology structures the nature in different levels of Reality, humans have different strata, levels, and plans of gnoseological perception that structure and concretize their historical complexity in their cosmological context. Hence we can also add the identity in the Cyber-Space-Time: the virtual identity.

Thus, educational curricula must consider the complexity in all levels of identity that human race is shaped, without falling into reductionist, one-dimensional or homogenized logics. Higher education students must learn that our identity is composed by multiple dependencies with our social and natural environment. “Eco-bio-anthropo-social conceptual loop is a loop in which the thought of natural complexity should allow developing the thought of social and political complexity, [9: 120]. From this vision, our identity is a unique result of multiple relationships. Every culture is more or less hybrid,

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<sup>1</sup>Gaia is the primal goddess personifying the Earth in Greek mythology.

mixed, made of intersections, feedback loops... There are no finished or perfect cultures because each culture carries sufficiency, insufficiencies, functionalities, and dysfunctionalities.

Therefore, it is necessary to promote a mindset transformation that facilitates the development of a “complex thought” capable of building a new kind of identity for the emerging global citizenship [10]. Our planetary identity is based on the idea that humans are part of nature (governed by natural laws), whose historical approach addresses together the past of people, life, Earth, and the universe [6]. This integral view of cosmic, planetary, and human history is known as “Big History” by the scientific community [3, 4], and allows us to understand better the complexity of social relations with nature, where mankind is considered an important element of co-evolutionary processes.

### 18.3 A Brief Summary of the Big History: The Human Co-evolution in Gaia

While it is true that Big History framework does not directly affect the current situation, it gives us a bigger temporal perspective to transgress the commonly accepted concept of sustainable development. I aim to redefine sustainability as a process of integral co-evolution with Gaia. All assessments we conceive today, as an interconnected world society, will affect future life models of our children and grandchildren. That is why we must learn more about cosmic, physical, geological, and biological frameworks that we belong as a human species. This view is aligned with the biologist Stuart Kauffman thought [11: 4-5]: “what some are calling the new sciences of complexity may help us find anew our place in the universe, that through this new science, we may recover our sense of worth, our sense of the sacred.” For this reason, the recognition of the cosmic origins of the human condition we can learn to appreciate better the importance of fulfilling the SDG and safeguarding life on Earth. Altogether, the process of *mapping* the Big History is based on the scientific consensus reached by the international community in astronomy, cosmology, physics, geology, biology, chemistry, anthropology, paleontology, archeology, ecology, history, geography, sociology, demography, economy, and so on [3, 4].

According to the scientific consensus of Big History, the humanly known universe arose about 13.7 billion years before present (BP), with the explosion of the *Big Bang*. Earth formation occurred between 5 and 4.5 billion years BP, and the miracle of life appeared around 3.8 and 3.5 billion years BP. During the first half of this period, the forms of first-born life on Earth remained at very simple complexity levels (as archaeobacteria or eubacteria), but the appearance of free oxygen in the atmosphere originated the first complex cells (eukaryotics), some 2 billion years BP. The Cambrian explosion of metazoans took place about 1,5 billion years later, some 542 million years BP. Since then, the biological variety has increased rapidly, forming a wide range of multicellular organisms that are developing survival strategies with very unique energy

flows, such as the food chain.

While it seems that life arose in the depths of the oceans, it only managed to reach the mainland about 450 million years BP. Only 250 million years after reaching the Earth's surface came the first warm-blooded animals, where dinosaurs highlighted during the Jurassic period until they disappeared 66 million years ago by a supposed asteroid impact on Earth. As Christian [3: 162] noted, this circumstance gave rise to hegemonic period of mammals, from where emerged later the first bipedal hominids around 7 million years BP. Thanks to carbon-14 testing performed on fossil remains found to date, we can know in an approximate way the dating of first Australopithecus, which seem to be about 4 million years. *Homo Habilis* dates from 2.5 until 1.9 million years, those of *Homo erectus* are around 1.9 million years, and those of *Homo neardenthalis* and *Homo sapiens* point about 200,000 years ago. With the extinction of *Homo floresiensis* about 13,000 years ago, *Homo sapiens* is the only survivor of the human species that co-inhabits and coevolves on planet Earth with the rest of the animal biodiversity, plants, insects, bacteria, etc.

Co-evolution is a term coined by biologist Paul Ehrlich and botanist-environmenta

list Peter Raven in 1964 [12]. In their joint work *Butterflies and Plants: A Study in Coevolution*, they approached the reciprocal evolutionary influences of plants and insects that feed on them: "an approach to what we would like to call coevolution is the examination of patterns of interaction between two major groups of organisms with a close and evident ecological relationship, such as plants and herbivores" [12: 586]. While the idea of co-evolution was not new and had already expressed in previous theories, the use made for Ehrlich and Raven allowed thinkers from other fields of application make new interpretations. In 1980, evolutionary ecologist Daniel Janzen was the first to define the concept of coevolution in his paper *When Is It Coevolution?* [13]. "Coevolution may be usefully defined as an evolutionary change in a trait of the individuals in one population in response to a trait of the individuals of a second population, followed by an evolutionary response by the second population to the change in the first", Janzen [13: 611] explain adding that "diffuse coevolution occurs when either or both populations in the above definition are represented by an array of populations that generate a selective pressure as a group." Thus, ecological interdependence requires three basic principles: 1) *specificity*, where the evolution of each specie is due to the selective pressures of the other; 2) *reciprocity*, when both species jointly evolve; 3) *simultaneity*, both species evolve simultaneously. So the co-evolutionary process has been used in a relatively restricted sense in the context of biological evolution.

But the sense of "coevolution" used in this research goes beyond to discuss in bioethics: including both the degree of mutual phylogenetic partnership as the degree of mutual change in the co-adaptation, but also global processes of macroevolution and specific processes of microevolution [14]. Coevolution is defined, then, as a reciprocal evolutionary change among species and their natural environment that, during the complex development of inter-retro-actions

with each other, mutually modify each other constantly. This view is used by researcher Rolf Zinkernagel [15] – Nobel Prize for Medicine in 1996- to explain how the immune system has co-evolved with microbes that cause infectious diseases, and also with the distinction between biological and social evolution introduced by historians Andrey Korotayev, Alexander Markov, and Leonid Grinin [16]. Coevolution is a feedback process very present in nature and has been basis for agricultural and industrial exploitation of human beings in their historical evolution on Earth. As explained by ecological economist Richard Norgaard [17: 39]: “with industrialization, social systems coevolved to facilitate development through the exploitation of coal and petroleum. Social systems no longer coevolved to interact more effectively with environmental systems.” With Industrial Revolution, began an era of hydrocarbons that drastically changed co-evolutionary processes of the prior agricultural stage of mankind. When social systems began to exert strong pressure on environmental systems, the stock of energetic and material resources decreased very quickly: starting an evolutionary period of planetary unsustainability.

The globalized society of 21<sup>st</sup> century must become aware, urgently, of socioeconomic unsustainability of “four-engine-of-globalization”: science, industry, capitalism, and technology [18: 104]. They are seriously jeopardizing both future human generations and the rest of natural ecosystems. It is necessary to organize transdisciplinary knowledge to understand that our specie evolution is intrinsically interlinked with constant co-evolution processes that different life forms are developing on our planet Earth from billions years ago. It is a multidimensional coevolution that unfolds through inter-retro-actions between different levels of cosmic, planetary, regional, national, and local reality, where an extensive network of universal interdependence is established with ecological, biophysics, social, political, cultural, economic, and technological phenomena. Hence the uncontrolled exploitation of natural resources for the manufacture of industrial products has become an issue of great concern in the international agenda, where different geopolitical actors study and analyze, for decades, cross-border phenomena that affect all life forms.

In this context, biomimicry emerges as a transdisciplinary science that deals with studying the complexity of inter-retro-actions developed between dynamic systems that make life (humans, animals, plants, etc.), within an environment which houses the ideal conditions for coevolution. Mankind is the unique species that participates in a cosmic dance starred by matter-energy phenomena whose symphony reminds us that we are active players in the coevolution of a common world shared with ecosystems of Gaia. “We now recognize the Earth as a single self-creative being who came to life in its rotating dance around the space” says biologist and futurist Elisabet Sahtouris [19: 25-26], adding that “as we gather the scientific details of the dance of life on our planet (...), the evolution of our species takes a new meaning in relation with the whole.” Hence the systematic degradation of nature makes us accomplices of a global ecocide, since the ecological footprint [20] is perpetuated by our active participation in consumerist dynamics and our bioethics passivity

before the destruction of life on our planet Earth, which is our sacred common good. “There are few more alarming indicators about the brutal climate imbalance that we have implemented, and the consequences will be terrible (ecocide and genocide, if you want to express in a synthetic formula),” argues the philosopher Jorge Riechmann [21: 333]. Our common future is built today and we cannot fail to future generations. With such imbalances, future generations will suffer the climatic consequences of global warming caused by our current consumer culture (chronic shortage of resources, ecosystem changes, loss of biodiversity, glacier melting, rising sea level, deforestation, pollution of soil, water and air, etc.). For all those reasons, biomimicry represents a paradigmatic shift in the epistemological construction of knowledge because its multi-referential epistemic frame goes beyond of traditional moral issues of human welfare to integrate new technological developments that radically altered the vital phenomena of own nature.

From this cosmodern vision, I propose that existing debate on SDG does not have to find solutions for the increasingly complex problems that arise in the current economical system of the world-society of the third millennium. SDG should promote the transformation of capitalism’s production system inspired by biomimicry approach. Affirming that economic growth is good for itself, postulating that human quality levels can be measured by GDP and GNP of a country, represent an intellectual fraud of danger consequences in the era of global ecological crisis. While it is true that capitalist system has brought enormous material benefits, its functionalist view subordinates everything to the maximum economic profit and the indiscriminate consumption at the expense of nature. It does not work to debate between communism, anarchism, socialism, capitalism or any other political theory of social organization derived from classical mechanics mental structures (where there is just one level of reality), but to mimic our own nature. “If we want to get along with Gaia, it is precisely how we must see ourselves, as one vote in a parliament of thirty (or perhaps even a hundred) million seats, a species among species” says biologist Benyus [22: 24]. Why the human species continues mortgaging the future of millions of species by its absurd logic of irrational consumption, which involves the exploitation of natural resources? Why do we believe in the epistemological illusion of unlimited economic growth when it has never existed any living species in nature, which grow endlessly to infinity?

## **18.4 Biomimicry: A Sustainable and Resilient Meta-Model**

Human irrationality in patterns of consumption and production of the current capitalist system is unsustainable and are also causing serious consequences in the environment: climate change, desertification, destruction of natural resources, pollution of water and air, global warming, etc. In this sense, if the principle of biomimicry is reclaimed as meta-model (economy, engineer, archi-

itecture, design, urbanism, industry, technology, artistic, political, educational, energy, etc.) to achieve a perdurable sustainable development, it is necessary a small mention of some thinkers who have proposed to learn from nature to build a more just, democratic, and better integrated with the biosphere society. A good example is the biologist and ecologist Barry Commoner [23], with the formulation of the basic “laws” of ecology: 1) *everything is connected to everything else*. There is one ecosphere for all living organisms and what affects one, affects all. 2) *Everything must go somewhere*. There is no “waste” in nature and there is no “away” to which things can be thrown. 3) Nature knows best. Humankind has fashioned technology to improve upon nature, but such change in a natural system is likely to be detrimental to that system. 4) *There is no such thing as a free lunch*. Exploitation of nature will inevitably involve the conversion of resources from useful to useless forms. In his later book *Making Peace with the Planet*, Commoner [24: 15] notes that techno-sphere prevalent in industrialized societies “is in war” with the biosphere, causing global ecologic crises impossible to be hidden.

Those basic laws of ecology have a strong link with the notion of “ecoliteracy” or “ecological literacy” developed by physicist Fritjof Capra [25] to understand the five organizational principles of ecosystems to build sustainable human communities: 1) Interdependence. 2) Cyclical nature of ecological processes. 3) Tendency to associate, establish links and cooperate as essential characteristics of life. 4) Flexibility. 5) Diversity. In short, Capra [25: 20] argues that “understanding the life must be seen as the scientific vanguard of the paradigm shift, from a mechanistic world conception through an ecological conception”, postulating that human systems should be governed by the key criteria of a living system: a) *organizational pattern* or configuration of relationships that determinate the essential characteristics of the system; b) *structure* or physical embodiment of the organizational pattern of the system; c) *vital process* or involved activity in the continuous physical embodiment of the organizational pattern of the system [25: 175]. In other words, Capra believes reconnecting with the web of life means rebuilding and maintaining sustainable communities in which we can satisfy our needs and aspirations without diminishing the chances of future generations. For this task we can learn a lot from ecosystems, true sustainable communities of plants, animals, and microorganisms. To understand them, we must become ecologically literate. “Being ecologically literate, being *ecoliterate*, means understanding the organizing principles of ecological communities (ecosystems) and use these principles to build sustainable human communities. We need to revitalize our communities including education, business, and policies [25: 307].”

The biomimetic approach is one of the most innovative responses in recent years to protect the environment and improve the quality of life through new sustainable habits of consumption and production. The term *biomimicry* comes from the ancient Greek *bios* (life), and *mīmēsis* (imitation). In the nineties, the term biomimicry would be used in disciplinary fields of material sciences, cosmetic research, and robotics, until the American science writer

Janine M. Benyus popularized it with her book *Biomimicry: Innovation Inspired by Nature*. Since then, biomimicry emerged as a new science that considers and values of nature as model, measure, and mentor: looking for the inspiration and imitation of the natural process to be applied into social systems, and thus find innovative solutions to complex problems (such as SDG). “Biomimicry uses an ecological standard to judge the correctness of our innovations. After 3.8 billion years of evolution, nature has discovered what works, what is appropriate, and what endures,” notes Benyus [22: 13], affirming that biomimicry “begins an era based not on what we can extract from the natural world, but what it can teach us.” Biomimicry represents a theoretical-pragmatic symbiosis between citizens from the North and the South, and also a fundamental tool to face the climate change. In this line of thought, Benyus recognized nine basic operational principles of Life in the Nature that can be used as example of beneficial model for human behavior:

1. *Nature runs on natural sunlight*: the energy absorbed by almost all natural communities comes from the nuclear fusion that sun makes at 150 million kilometers. “The solar, wind and tidal energies, as well as biodiesel, all derive from the current sunlight” [22: 321]. When we burn fossil as oil, natural gas or coal, we are using the old sunlight, which remained trapped (compressed in an environment without oxygen) in the bodies of animals and plants of the Carboniferous period. When the combustion is made, we are completing “the decomposition process suddenly, pouring the coal stored into the atmosphere in large quantities, ignoring the ecosystem precept of no *big flows* [22: 321].” Taking into account that our biosphere is almost a closed and autopoietic system [26], this attitude would be equivalent to burn the furniture inside our home with the windows closed. Unfortunately, fossil fuels are too cheap and the current consumer society, addicted to energy, goes to full exploitation of these natural resources. A good example would be the leaves, which perform photosynthesis (biochemical decomposition of solar energy in nutrients) with amazing 95% of quantum efficiency, four times more efficiency than solar panels built by human.
2. *Nature uses only energy and resources that it needs*: While it is true that second law of thermodynamics converts energy into heat, and a portion of energy is no longer usable, nature knows how to get energy efficiently through different ecosystem connections. In order to make an optimum use of limited habitat, each organism has found a niche and only uses what it needs to survive and evolve. Thus, the lessons of natural systems can guide us to establish new uses for energy. We must consider what we are maximizing (production) and focus more on optimization, as natural systems do when they invest their energy in maximizing diversity to become more efficient in the process of recycling organic nutrients and minerals [22: 322].
3. *Nature fits form to function*: nature is a highly cooperative system made

by dense interactions between its components. The whole ecosystem network has been built in the limits of available resources and as a result, the entire ecosystem has reached an internal coherence of intricate organic patterns which form is adapted to the function. The nature optimizes rather than maximizing. On the contrary, our industrial ecosystems “continue betting on higher rates of productivity and growth, for a maximum flow of material extracted from Earth and converted into shiny new items. 85% of manufactured goods quickly become waste” [22: 323]. Indeed, the current globalization economy defines its success by fast growth and creates the illusion to measure progress and human development by indicators such as GDP and GNP. By contrast, organisms co-evolving in nature adapting themselves into the changes of others because their structure play several functions in its environment. “The lesson is that we have to delay the material manufacturing and put the emphasis on quality and not quantity of new items [22: 323].”

4. *Nature recycles and finds uses for everything:* “One of the key lessons of ecology systems is that when a system accumulates biomass (total weight of living matter), it needs more recycling to avoid collapse” [22: 312]. The existence of trophic chains in ecosystems has a circular organizational scheme where producers, consumers, and decomposers have evolved together in a closed loop to prevent the loss of resources: “all waste is food, and everyone is reincarnated into the body of other” [22: 313]. The problem of human culture of production and consumption is that it continues accumulating biomass without a network of closed loops. In this sense, Benyus explains several examples of “zero waste economy” in European Nordic countries (especially Denmark) where there are small trophic networks of industrial ecology with closed loops, where the exchange of information and the mutual wish to utilize the waste causes that all manufactured products coming from market, re-entering into the production system through legislation recovery and reimbursement systems.
5. *Nature rewards cooperation:* in mature ecosystems the cooperative strategies among organisms are as important as competition. According to the endosymbiosis hypothesis of Lynn Margulis [27], the symbiosis between two species is a fundamental element of evolutionary progress from billions of years ago. Natural ecosystems operate in a complex symbiotic network of mutually beneficial relationships and when they grouped a large number, they make up organs and organisms. In fact, the endosymbiotic theory postulates that our body is actually a combination of unicellular organisms that have conformed a huge pluricellular organism. Translated into the human production system, the Japanese industrial ecologist Michiyuki Uenohara notes that “we have plenty arteries (main tracts where flow products from the industrial heart to the body of economy), but we also need veins, return tracts of used products to purify and reuse their materials” [22: 318]. The lesson learned, there-

fore, is to build an economy where the arteries and the veins have the same importance, what would imply the imitation of ecological systems of closed loops that reuses the resources. According to Benyus [22: 319], an example of pre-competitive cooperation is constituted by the American brands Chrysler, Ford, and General Motors, developing partnerships for the manufacture of standard material that allow them to reuse parts of each other.

6. *Nature depends on and develops diversity*: the enormous development of diversity in nature is due to their experience of billions of years in “trial and error”. Nature is characterized, in consequence, by the multi-referential approach that randomness produced by the entropy (rupture of the order) has enabled with its flexible opening to new anomalies. This eco-biological flexibility has enabled a large variety of animals and plants over billions of years around the entire habitat of planet Earth. Therefore, the lesson we learn from nature is that our industrial system must be flexible to be adapted to the emerging needs of global citizenship, and be as diverse as its own environment to respect regional, cultural, and material uniqueness of the place.
7. *Nature requires expertise and resources*: generally, natural ecosystems are connected in a relatively closed manner in the space-time. There is a rich biodiversity in the local ecosystems where many local species co-evolve together to be adapted to the changes. Unfortunately, the current capitalist trend is a global economy without frontiers where manufactured goods are produced in far countries geographically separated. In this sense, we must learn from the local knowledge and experience that indigenous people have, because “the idea of an adapting economy to the land and take advantage of its local attributes would bring us closer to the organisms that have evolved until become local experts [22: 339].
8. *Nature avoids internal excesses*: “The biosphere (the layer of air, land, and water that sustains life) is a closed system, meaning it is not imported or exported materials (apart from the naughty meteorites)” [22: 332]. The autopoietic character of the biosphere get that life maintains the necessary conditions to regulate itself through a constant exchange between organisms (photosynthesis, respiration, growth, mineralization, decomposition, etc.). Unfortunately, the global industrial system is an opened system where “nutrients” become “waste”, without any significant recycling process. This exploitation dynamic of natural resources and pollution is changing drastically the natural process because they cannot recycle the huge amounts of CO<sub>2</sub> emitted into the atmosphere (currently 355 of each million of molecules). The only answer is an industrial ecosystem that can be integrated in the biosphere without harming it.
9. *Nature taps into the power of limits*: nature has learned that living with finite resources is a powerful resource of creativity. In nature there are

internal feedback mechanisms that optimize the use of resources of the environment in constant balance, with moderation and without devastating it. That means not mortgaging the future because, otherwise, it would die. The lesson is that our current production system cannot continue to push the limits of the planet. Nature teaches us to flourish within biological limits, without being in continuous predatory expansion. On the contrary, we must “*adapt human systems to ecosystems (biomimicry), managing greater efficiencies (eco-efficiency) and act on the demand with self-containment measures (generalized demand management)*” [21: 28].

In short, the nine principles of life from nature that Benyus [22] identifies are incompatible with the current capitalist socio-economic order. “It could even be said that capitalism is the metaphorical antithesis of the natural process of life: in it prevails exclusion, squander, deregulation, what we call today as *relocations*, as well as unaware speculative flows to real production of goods and services” notes the natural philosopher Luciano Espinosa [28: 66] compared to natural systems of the biosphere where “operate inclusive circuits of all member of the network, which are attached to the ground, tied to the satisfaction of the basic needs and the constant recycling of matter and energy” (ibid). This comparison seeks to understand the complexity of life. A bioethics understanding that should be promoted by the SDG to face the global techno-economic dynamics that are destroying life on Earth. SDG should aim to establish itself as the political, educational, and epistemological tool able to modify the socio-ecologic metabolism through new symbiosis between natural ecosystems and human cultures systems of production. To do this, Riechmann [21: 171] claims to address the principle of biomimicry in a broader sense, “to understand the operating principles of life in its different levels (particularly the eco-systemic level) with the goal to *rebuild human systems in order to fit them in the natural systems harmoniously.*” In this way, Riechmann [21: 211] also suggests six basic principles for the ecological reconstruction of economy from the biomimetic perspective: 1) Homeostasis or “steady state” in biophysical terms. 2) Living from the sun as energy source. 3) Close material cycles. 4) Do not carry too far the materials. 5) Avoid xenobiotics like POPs (persistent organic pollutants), GMO (genetically modified organisms), etc. 6) Respect diversity. Together, we must *rebuild our human systems* failing to grow economically to focus more on the qualitative development. The economy is a subsystem of nature. Then, we must learn to consume the only necessary natural resources for a sustainable human development.

With this ecological vision, learning-teaching processes of the educational system should promote a biomimetic dialogue that fosters a planetary critical consciousness through global solidarity reflections and, ultimately, the emergence of new social organization networks to compliance with the SDG [14]. Metaphorically speaking, education is a living organic structure in a constant process of adaptation and co-evolution with the environment. For this reason, Education for Sustainable Development (ESD) program should not only

think about how to integrate the biomimetic principles in local and national educational curricula. ESD should also think about how to apply them as networks in an interconnected world. Since the scholarly microcosm embodies the macrocosm of social structures, the common future of humanity among the planet Earth requires a true political, epistemological, and educational transformation that implies the emergence of a cosmodern paradigm characterized by the change of hierarchies to networks in the social organization field. The conceptual notion of “cosmodern paradigm” is aligned with the idea of “Cosmodernity” proposed by Nicolescu [5] and with the “*cosmodernism*” of Moraru [29]. In the thoughts of both authors, there is an important bioethics fundament of responsibility with world problems, an epistemological call to overtake binary and reductionist knowledge, and a contextual relationship between human beings and the cosmos.

## 18.5 Cosmodern Education for a Sustainable Development

Education is the main key to achieving a sustainable development in Gaia: being the seed that we must cultivate for our present and future flourishing. We need to develop an integral view that includes the human being within co-evolutionary processes of Big History to achieve the SDG. “Sustainability is not just a problem between us the humans,” explains environmental educator Maria Novo [30: 368], “it is also a serious problem of our relationships with the biosphere, the way we appropriate resources, exploit nature, manage the commons, and how we consider the limits of ecosystems.” For this reason, it is urgent to transform models of predatory behavior that human species exercise over Gaia, as well as the unequal distribution of wealth that only benefit a minority. In this regard, the identification of operational principles and strategies that life is developing in nature represent biomimetic models that help us to live in Cosmodernity: where human beings co-evolves in sustainable and resilient harmony with all the ecosystems of our planet.

Educate to live in the paradigm Cosmodernity means introducing transdisciplinary and biomimetic approaches at all levels of formal education, but also in non-formal and informal areas to develop the full potential of the human condition. The oldest example is found in many native and indigenous peoples who are still training individuals through a “bio-literacy look” that persist for thousands of years. Human training of indigenous and aboriginal peoples is focused on strengthening linkages and relations between human beings and nature. This vision is far from educating people who are submissive workers in a globalizing economic system that tends toward homogenization of cultural diversity and ends with a large portion of the biodiversity on Earth. For this reason, the *United Nations Declaration on the Rights of Indigenous Peoples* recognizes “that respect for indigenous knowledge, cultures and traditional practices contributes to sustainable and equitable development and

proper management of the environment” [31: 2]. All worldviews of indigenous peoples are a good example for a resilient and sustainable development because they have been developing excellent socio-ecological practices during thousand of years. While we cannot fall into the romantic idealization of the indigenous community, all their rich epistemic multi-referentiality is in full harmony with the co-evolutionary limits and margins that ecosystems set in a self-organizational way.

In 2009, General Assembly of the United Nations proclaimed April 22 as the “International Day of Mother Earth” to pursue this harmony with nature. Since then, the General Secretariat of the UN has published annually a resolution on Harmony with Nature to recognize the Earth and its ecosystems as our common home. The aim is the Member States achieve a fair balance between economic, social, and environmental needs of present and future generations. For this reason, we must face the paradigmatic crossroads of climate change from an “ecology of knowledge” [32] to develop and improve all human dimensions through a transdisciplinary organization of knowledge that combines scientific reason with other epistemic, spiritual, religious, emotional, political, rhetorical, poetic, artistic, and philosophical aspects. Undoubtedly, dialoguing with indigenous and aboriginal wisdom enable us to develop more resilient epistemological horizons. When this multi-referential and transdisciplinary perspective is adopted, education becomes an epistemic tool that searches individual development of people within a vast network of relationships with other human beings, but also with nature and the cosmos. That is why all theoretical models that reduce sustainable development to just three dimensions (economic, social, and environmental) are failing to address the inherent complexity of the interdependent network of systems that are interconnected at various levels of ontological reality. This is the epistemic point of departure to create a holistic and transdimensional education to strengthen ties with sustainability to achieve the SDG in 2030. The potential development of global citizenship represents the genesis of a cultural metamorphosis that reinvents our relationship with the sacred: moving from the exploitation of nature to create new biomimetic models to learn from it in order to achieve a lasting sustainable development.

Educate to live in Cosmodernity requires, therefore, a civilizational mindset that transforms the core of the paradigmatic collective imagination that Modernity began in the West in the seventeenth century. It was established worldwide through computerization of economic globalization. If we want to achieve the SDG it is essential to reflect on the historical origins of our educational systems. Education can be both a way to aggravate the socio-ecological problems, but also an instrument of change that helps us to solve them. From a historical point of view, ideological discourse created by the power groups during Modernity has used educational knowledge to establish a set of behaviors, norms, and actions that have served to structure hierarchically Western modern societies. For this reason, education becomes a fundamental key to change historical civilizational direction and walk towards sustainability. Cosmodern

education promotes a transdimensional understanding where the human being is seen as a unique species that co-evolving in a shared ecosystem with more than ten million other species. We must learn to respect, preserve, and regenerate them. We cannot extinguish the infinite wisdom accumulated over billions of years of planetary biodiversity. It is urgent to transform mankind's domination approach to nature, into an approach of stewardship. The processes of domestication (about 10,000 years ago with Agricultural Revolution) and industrialization (about 250 years ago with Industrial Revolution) have accelerated exponentially ecological degradation. Now it is the time to learn to co-evolve as a sub-system within the biophysical limits of Gaia: our Earth-Homeland [33].

From this co-evolutionary vision that integrates the human being in his earthly and cosmic context, the concept of sustainable development gain a new sidereal dimension to see how all living forms that co-inhabit in Gaia represent an exceptional miracle in the universe. This type of "Cosmic Education" was formulated in 1935 by the biologist, medical doctor, psychiatrist, anthropologist, philosopher, educator, and pedagogue Maria Montessori. As shown in Figure 18.1, the Montessori method is a set of knowledge, practices, and recommendations characterized by the emphasis on the interdependence of all natural elements. This method seeks to create conditions for children 6 to 12 years – future global citizens- to strengthen their feelings of cooperation, respect, and love in relations with the own nature and the cosmos. "Life is a cosmic agent. How shall this truth be presented to the children so as to strike their imagination?" Maria Montessori questioned [2: 32]. Aligned with Big History, Cosmic Education is based on giving children freedom to explore, study, and learn about the early universe, the origin of life, human evolution, language development, and the history of mathematics. They learn to appreciate how diverse cosmic forces operate and interact according to the complex laws and co-evolutionary strategies of nature: "another – and stronger- factor in evolutionary processes is concerned with the cosmic function of each living being, and even of inanimate natural objects, working in collaboration for the fulfillment of the Purpose of Life" [2: 42]. This cosmic vision in pedagogy is an essential seed to achieving the blossoming of a conscious global citizenship ready to comply with the SGS [14].

In sum, Montessori's Cosmic Education promotes a sustainable human development where students feel creative, deeply, and self-aware about how the whole and the parts are interrelated. The epistemological core of this pedagogical approach is aligned with the thought of indian educator Jiddu Krishnamurti [34: 26]: "to learn the mind must remain highly sensitive, and learn implies we see every problem, not as an isolated event, but as a fact related to others." Hence Krishnamurti [34: 185] says, "We need, internally, a great revolution. And to have the possibility make this great psychological and mental revolution we must go beyond the limits of our own mind." For this reason, self-awareness and management of our emotional intelligence are essential elements that all models of education must include in their pedagogical



psychological transformation is more important than outer change. The outer fundamental changes are not possible unless there is a radical transformation, a true revolution in the psyche”, explains Krishnamurti [34: 192], “outer changes and reforms are necessary, but they are always destroyed by our inner state of confusion, disorder, and violence.” Therefore, it is clear that governments are failing in their educational reforms because they are trying to face complex problems of the current globalized world by making the same mistakes of the past. In this process, they are alienating millions of young adults in higher education who do not see any use in university attendance, especially in the West. In order to face the dangers of the future, with the collective aim to meet the SDGs by 2030, we will need a holistic, systemic, and transversal reflection on the appearance of human beings in the Big History, without forgetting the epistemic worldviews and cultural traditions of each particular context.

In the paradigm of Cosmodernity, scientific knowledge of an external physical universe converges with the spiritual knowledge of an inner emotional universe. “Our transdisciplinary education experience for sustainability includes the spiritual dimension as a core for creating relevant knowledge within our societies, at local and global levels,” explains anthropologist and economist Cristina Núñez [36: 109]. This means that educational success cannot be reduced to a simple quantification carried out by standardized tests of reading, science or mathematics, as happens with PISA<sup>2</sup> tests developed by the OECD. The real educational success lies in understanding that students have spiritual, emotional, and psychosomatic experiences with the intention to develop deep connections with other people, with life, with nature, and with the cosmos. Theory and practice belong together in the paradigm of Cosmodernity, as ideas and sensorial experimentation converge to develop a meaningful learning in all educational levels. This educational vision of human training is defended by neurologist Antonio Damasio [in 37: 34], who considers: “it is necessary that political and educational leaders come to understand how important is the knowledge about emotion and feeling because many of the reactions we consider pathological have to do with emotions, mainly with social emotions, and with the ease that social conflicts are triggered.” This kind of emotional education seems to be a fertile and prosperous path that leads us to the heart of an education that prepares us to achieve sustainable development.

Educating is a transcendental act in the lives of people that forces us to recognize problems outside the classroom. It is necessary to challenge our own educational paradigm to encourage a culture of peace and sustainability that promotes social and democratic transformation. “This is not another reform, but a real structural transformation in the mindset, raise, implement, and management basic education”, argues educator Moacir Gadotti [38: 47], who claimed the need to create a “pedagogy of the Earth” or “eco-pedagogy”

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<sup>2</sup>The Program for International Student Assessment (PISA) report is a worldwide study by the Organization for Economic Co-operation and Development (OECD) in member and non-member nations of 15-years-old school pupils’ scholastic performance on mathematics, science, and reading.

that goes beyond the school logic and reach the entire society. For Gadotti [38: 93], eco-pedagogy “is concerned with the ‘promotion of life’, relational content, experiences, attitudes, and values”, so education should not be confused with the formal and institutionalized schooling processes. While the

schooling logic is focused in the speech, educational logic is focused on the process. “Founded on the principle of competitiveness, selection, and sorting, traditional pedagogies do not help in the development of citizens who needs to be more cooperative and active” [38: 87]. On the contrary, most educational organizations that do not behave like an isolated island in their social environment which develop formal, non-formal, and informal networks ,are already fostering a sustainable mindset. A good example is the formal education system of Finland, where secondary schools train students in an interdisciplinary way through complex concepts such as sustainability, climate change, globalization, etc.

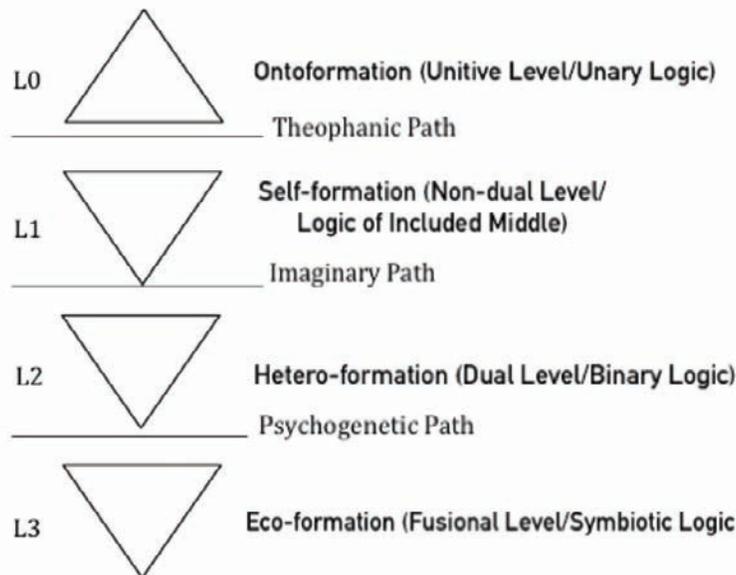
In this line of transdisciplinary human training, psychologist and education scientist Gaston Pineau [39] and medical and anthropologist Patrick Paul [40] have proposed different models. In both theoretical models of human training, it seeks to think in complex ways to understand the interrelationships of the whole with the parts and vice-versa. Consequently, knowledge and human learning imply the development of self-regulating, self-organizing, and self-transforming processes that involving different dimensions of human complexity. According to the “Tripolar Theory on Training” postulated by Pineau [39], where the methodology explores life stories and various formulations that subjects give to their training paths, there are three essential processes in the human training: personalization, socialization, and ecologization. This theoretical perspective led him to formulate three concepts of human training: the “*self-training*” in relation to oneself; the “*hetero-training*” in relation to the others; and “*eco-training*” in relation with the world. Pineau [39: 130] explains that term “*self-training*” came before the other two and favored the development of research on “empowerment of the actors for the appropriation of their power of training.” The concept “*hetero-training*” refers to the social dimension of education and train action in relation with other people and the term “*eco-training*” means training processes with respect material environment [39: 132]. In turn, Pineau highlights that none of these training dimensions should be prioritized over another, and that is why he suggests the term “*co-training*” to describe certain educational processes focused on the interrelations of actors, where nonhierarchical inter-retro-actions occur.

It is here that Paul [40] advocates for an articulation of all these human dimensions postulated by Pineau to develop a fourth dimension that he calls “onto-formation.” According to his “Anthropoformation Theory”, Paul [40: 28] argues that human training is the “global and general process (at the same time particular and unique, but also social and collective) that articulates the interactive relations between eco-formation, hetero-formation, self-formation, and onto-formation.” In addition to increasing a new dimension, Paul [40] also proposes a detailed modeling of the different levels of educational reality of the

transdisciplinary subject, which is summarized in the following figure made by Sommerman [41: 808]:

As Sommerman [41] summarized in Figure 18.2, the model proposed by Paul [40] is composed of four dimensions of human training: ontoformation (L0), self-formation (L1), heteroformation (L2), and ecoformation (L3). According to Paul [40: 531-535], the level of reality N0 is unitive and corresponds to the onto-formative dimension, where a unary logic is necessary to understand virtuality and potentiality that goes beyond of all form and image of this level. L1 is a non-dual level corresponding to self-formative dimension, where all potentialities contained in L0 are manifested, for whose understanding is required the logic of the included middle. The L2 level concerns to dual interactions of hetero-formative dimension, whose binary logic runs about life and death, the subjective and the objective, the individual and the collective, etc. Finally, L3 is the fusion level corresponding to an eco-formative dimension where the symbiosis is the functional basis of living systems of nature. In turn, these four dimensions are epistemologically crossed by the transdisciplinary subject through different stages: moving from eco-formation (L3) to hetero-formation (L2) constitutes the psychogenetic path of human training; moving from hetero-formation (L2) to self-formation (L1) is the imaginary path, and the passage from self-formation (L1) to onto-formation (L0) is the theophanic path of a human being's overall training [40: 541]. As a whole, multidimensional modeling proposed by Paul and Pineau [42] for human being training represents a new transdisciplinary approach that helps us to face planetary challenges that humanity has to meet the SDG. Therefore, educating to live in Cosmodernity means developing the potential of these four dimensions for a transdisciplinary training of a complex human being in constant material, energetic, and informational co-evolution.

This *anthropo-formative* vision is complemented for a complex model of emotional training that we cannot forget in Cosmodernity: the called emotional education. This educational approach is a psychopedagogical innovation focused on the endogenous development of people to shape their interiority inside a universe of emotions. Emotional education is supported by the scientific foundations provided by social psychology, neuroscience and psychoneuroimmunology, and it seeks to meet social needs that are not met by traditional academic subjects. So emotional education is within the latest movements of pedagogical renewal and regeneration. This emotional perspective redefines the "Theory of Multiple Intelligences" and potentiates the *self-, hetero-, eco-, and onto-formation* because it provides meaningful learning of cosmodern human training. In short, emotional feelings, spirituality, and interiority are important facets to achieve mental, social, and environmental balance needed to improve the human welfare in a resilient and sustainable manner with all ecosystems of the Earth. What is the role of emotions to manage sustainability? How can emotions help us to achieve the SDG? Is it possible to speak about *eco-emotional education*?



**Figure 18.2:** Modeling the Anthropoformative Theory of Paul [40]. Epistemological levels of consciousness in different levels. Resource: Sommerman [41: 808].

## 18.6 Inner Education in a Universe of Emotions

From a historical point of view, human emotions have been little studied by modern scientific psychology, but in recent decades more attention went to this fundamental human dimension. According to the specialized literature, Michael Beldoch first used the term “emotional intelligence” in his book *The Communication of Emotional Meaning* in 1964. In early 1990, social psychologists Peter Salovey and John Mayer [43: 189] proposed the “Theory of Emotional Intelligence,” defining emotional intelligence “as the subset of social intelligence that involves the ability to monitor one’s own and others’ feelings and emotions, to discriminate among them and to use this information to guide one’s thinking and actions.” However, the term was popularized in 1995 with the publication of the book *Emotional Intelligence* written by psychologist and science journalist Daniel Goleman [44, 55-56], who reports five basic domains: 1) Knowing ones emotions (self-awareness); 2) Managing emotions (resilience/mood management); 3) Motivating oneself (self motivation); 4) Recognizing emotions in others (empathy); 5) Handling relationships (social competence).” Since then, there have been different theoretical models but they have never been exempt from criticism alleging lack of indicators or gauges of this type of

intelligence. But, how could we measure emotions and feelings? How to measure our passions and affects? According to scientific agreement, it is clear that emotional intelligence cannot be measurable today, at least with intelligence tests that have been applied since the 1910s to predict school performance of children. The educator Ken Robinson [45] states that most in intelligence quotient (IQ) tests only reflect a measure of linguistic, logical (mathematical), and spatial skills, but do not consider other intellectual dimensions such creativity. Hence the controversy between the scientific communities to assess what types of intelligence exist.

In 1983, the “Theory of Multiple Intelligences”, created by neuropsychologist Howard Gardner, became a pioneering model that opened the debate to redefine intelligence. Since then, numerous authors have been proposing and criticizing models focused on the study of intelligence. While the traditional definition of intelligence was rather reductionist and focused on cognitive aspects, Gardner’s theory [46] focused more on the multiples ways in which we think and learn. Despite the great academic controversy, many schools of thought are using this model to understand the multidimensional nature of human intelligence. For Gardner and his team, there are eight types of intelligence and each person develops some more than others depending on their personal skills and paradigmatic social influence: 1) verbal-linguistic intelligence, 2) logical-mathematical intelligence, 3) visual-spatial intelligence, 4) musical-rhythmic and harmonic intelligence, 5) bodily-kinesthetic intelligence, 6) intrapersonal intelligence, 7) interpersonal intelligence, and 8) naturalistic intelligence. Extending these ideas about intelligence, Gardner and Hatch [47] suggest that interpersonal intelligence recognizes and responds to the moods, temperaments, motivations and desires of others; while intrapersonal intelligence focuses on self-knowledge and access to one’s feelings. Currently, they are also investigating the existence of the ninth multiple intelligence: the “existential intelligence.” Therefore, a theoretical and conceptual model of multiple forms of intelligence is very close to the “Theory of Emotional Intelligences” [43]. This suggests that emotional intelligence plays an important role in internalizing the resilient and sustainable behavior necessary for the compliance of the SDG because this biological phenomena goes beyond of our cultural constructions..

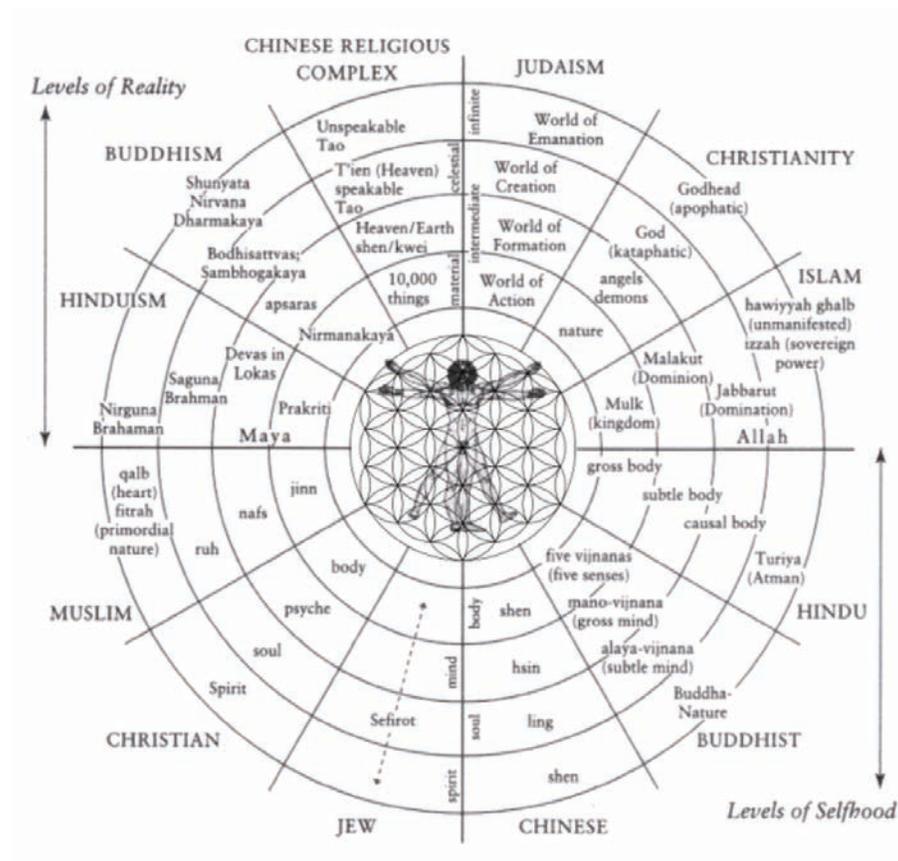
From a phylogenetic evolutionary standpoint, the human species has developed the ability to combine reason with an inner universe of emotions and feelings that have accompanied it for thousands of years during its evolution. Emotions have been passed down from generation to generation and are a feature and indispensable part of our human nature. Without them, we would be psychopaths with antisocial personality disorders. “As we all know from experience when it comes to shaping our decisions and our actions, feeling counts every bit as much – and often more- than thought” argues Goleman [44: 18], adding that “each emotion offers a distinctive readiness to act; each point us in a direction that has worked well to handle the recurring challenges of human life.” According to some sociobiologists, these automatic reactions

of *emotion-action* were recorded in some form in our nervous system and were crucial to surviving during the long period of human prehistory. Here it is important the specification introduced by the neurologist Antonio Damasio [48: 110]: “while emotions are actions accompanied by ideas and certain modes of thinking, emotional feelings are mostly perceptions of what our bodies do during the emoting, along with perceptions of our state of mind during that same period of time.” Thus, neuroscience affirms that emotional feelings “color” our life from beginning to end, regardless of our nationality, ethnicity, culture, race or religion.

In this sense, it is curious that most international events I have participated always talk about “universal values” and not about “universal emotional feelings.” In my opinion, this is a transcendental epistemic mistake we must correct if we want to achieve the SDG. When we try to identify the universal values that are present in all cultures of the world, we run the serious risk of homogenizing the rich and complex cultural diversity of peoples [10]. According to the estimation made by the philosopher Kenneth Shoulder [49], there are currently around 4,200 religions worldwide. In turn, the research project *Ethnologue* reckoned there were around 7,102 living languages for a population of 7.1 billion people in 2015. After colonization and imperialism, it is clear that epistemic approaches that “universalize” values almost always have a strong Western imprint, as happened with the Universal Declaration of Human Rights. On the contrary, by focusing the discourse of sustainability using a transcultural biological phenomenon, such as human emotional feelings, education gain a new epistemological perspective of *feeling-thinking* to build “another world is possible.”

## 18.7 Spiritual and Religious Dimension of the Human Condition

In addition to emotional dimension, the book *The Tao of Liberation: Exploring the Ecology of Transformation* written by the ecologist Mark Hathaway and theologian Leonardo Boff [50: 376] also advocate for the spiritual dimension: “The spirituality of each person is in some sense unique, and our own spirituality may draw on a variety of religious or philosophical traditions, as well as our own personal experience.” However, they also warn “most of humanity draws on religious traditions as a key source of spiritual insight. It is nearly impossible to consider spirituality without also considering the influence – both potentially positive and negative- of religion” [50: 376]. Therefore it is necessary to differentiate spirituality from the historical interests that have prevailed and continue to occur within religions. To this end, the work, *Why Religion Matters*, written by Huston Smith [51] is a good study that helps us to establish an interreligious dialogue of most practiced and influential beliefs today: Christianity (33% of the world population), Islam (21%), Hinduism (14%), Buddhism (6%), traditional Chinese religion (6%), and Ju-



**Figure 18.3:** Levels of Reality and Levels of Selfhood in the most influential religious beliefs (flower of life added by author). Resource: Smith [51: 224].

daism (0.25%) [49].

As shown in Figure 18.3, the diagram has a form of the mandala with the flower of life in the center representing the common wisdom of native indigenous peoples. The mandala addresses the interpretations that the main religious beliefs have about the relationship between reality and selfhood. At the top, the levels of reality are reflected in the levels of selfhood of the bottom through four circles of different intensity. This figure depicts the many similarities between of the six most influential religions practiced today by approximately 80.25% of current world population. If we also note that 16% of world citizenship is secular, not religious, agnostic and atheist, it means that only 4% of the world population, about 275 million people, practice the other 4,195 religious worldviews identified by Shouler [49]. Thus, the mandala serves us to recognize ourselves in the mirror of the other, of the infinite otherness,

since there are numerous bridges between these great religious dimensions.

Throughout mankind history, religion has constituted a risk factor for all the wars that took place, especially in the Middle East . This is an area of great instability due to a complex network of ethnic, racial, political, and economic factors that arise by the coexistence of three monotheistic religions: Judaism, Christianity, and Islam. Currently, inter-religious conflicts are suffered in countries such as Nigeria (Christians and Muslims), Israel (Jewish and Muslim), Thailand (Buddhists and Muslims), Sudan (Muslims and non-Muslims), Afghanistan (fundamentalist Muslims and non-Muslims radicals), and in Bosnia and Kosovo (Catholics, Muslims, and Orthodox). At the same time, intra-religious conflicts are giving more visibility within Islam, between Shiites and Sunnis, in suppressed countries as Syria, Lebanon or Iraq. In these countries, the so-called “Islamic State” is emerging and threatening the world through terrorism practiced by its followers in the “holy war” against the West.

All these confrontations seem to indicate that we have developed a wrong way to seek our spirituality. Instead of cultivating and researching the mind and our relation with the sacred, we have preferred to maintain dogmatic beliefs: mistaking them with religion and spiritual growth. For this reason, all liberating education must transgress these epistemic paradigms to promote an investigative mind that questions and find out for itself, rather than reproduce and imitate contents of a certain “holy book” written thousands of years ago. In line with this, the Indian theosophist Padmanabhan Krishna [52: 27] marks that “Jesus did not become Christ through a church or a belief, but through his own understanding and his own research. Buddha attained enlightenment and understanding through his own meditation, his own research. We must understand this and correct the situation in our educational system.” The pedagogy of freedom must guide at each individual of global citizenship in their own intellectual, emotional, and spiritual research, questioning the epistemic paradigms where they live in. What is my identity? Why is this my nationality? Why should I follow this particular religion? What are my responsibilities with nature given my human condition and ability for reflection? Only by researching and having our own *insights* we will learn to give these answers. Repeating the answers of Jesus, Buddha, Mohammed or other spiritual leaders we will not be cultivating our own conscience to safeguard life on Earth. Each response is unique and non-transferable.

Critical thinking and self-knowledge is one of the most important skills that students must learn to become spiritually literate. For this reason, it is important to reinvent the sacred from our own individual hermeneutic, which involves learning to dialogue in an intra-religious form. According to the philosopher, theophysicist, and expert in religious comparisons, Raimon Panikkar [53: 74]: “If interreligious dialogue is to be a real dialogue, an intrareligious dialogue must accompany it, i.e., it must begin with my questioning myself and the relativity of my beliefs.” The thought of Panikkar is a meeting point between East and West, his his works is an ongoing intercultural and interreligious dialogue that leads to mutual fertilization between cultures

and civilizations: where everyone learned from everyone. “Each language is a world of its own (...) each culture is a galaxy with its own criteria of goodness, beauty, and truth” [54: 29]. The truth is pluralistic and this means no one has all the elements for the judgment of other cultures. Pluralism makes us aware of our contingency and our limits to judge, showing how to coexist with a cultural diversity that implies galaxies of worldviews with own criteria of reality. According to Panikkar [55], every culture and civilization have three ontonomic orders (myth, logos, and mystery) and an interrelated cosmotheandric dimension. This means that Human History, Cosmic Existence, and Divine Destiny are inseparable. Thus, Panikkar [55] unifies and reconciles the physical cosmology and the religious cosmology, giving a new philosophical and spiritual sense to the *ontology of science*. This is the pure essence of the Cosmodernity paradigm [56]. In sum, the pluralistic consciousness reminds us that every culture or religion are intrinsically opened to be fertilized by others since the understanding of our human identity/condition in the universe requires comprehensive solidarity among all beings to bring us to the knowledge of the ontological structure of reality. Therefore, we must develop a comprehensive look at the teaching and learning processes that take place in the institutions of the educational system. But, how to educate to live in the paradigm of Cosmodernity?

## 18.8 Educating to Live in the Paradigm of Cosmodernity

Educating to live in the paradigm of Cosmodernity means developing new processes of meaningful learning by exploring different types of human intelligence (rational, spiritual, social, emotional, ethical, etc.) that help us to *feel-think-act* in response to our current emergency situation. Thus, Cosmodern Education cultivates the emotional, spiritual, and ecological literacy as its foundation to develop a sustainability mindset where science, culture, and spirituality are interlinked in the cosmos for a resilient and sustainable human development on Earth. This triple literacy helps students to develop a cosmodern consciousness. Emotional feelings, thoughts, and actions are part of the same phenomenon of inseparable interconnections that form the basis of our socio-ecological relations. In this sense, emotional education helps us to potentiate the meta-cognition pursued by anthropocentric and ecocentric approaches promoted in values education, global citizenship education, education for gender equality, environmental education, education for sustainable development, etc. Emotional education emerges, therefore, as a parallel psychopedagogical dimension that complements transcendently self-formation, heteroformation, ecoformation, and ontoformation. Cosmodern Education cannot be an act of transmitting values and knowledge, but a creative, constructive and transformative act. Students must learn to develop a continuous self-conscious dialogue to *feel-think-act* with their emotional feelings, thoughts, and actions.

According to educators Maria Candida Moraes and Saturnino de la Torre [57: 41-42], “humans act as a whole, where thought and feeling are in holomovement conjugating themselves, so it is difficult to know which one prevails over the other.” What this comparison of the two basic movements of retraction and expansion that physicist David Bohm [58] created in his “Theory of Holomovement”, Moraes and Torre argue that feeling-thinking is a flow of relational and dynamic emotions that interact with the mind, body, and action of individuals to transform their environment. Recognizing that emotions are the foundation of reason, as asserted by biologist Humberto Maturana [59], education is perceived as a holistic phenomenon with multidimensional implications affecting all dimensions of the human condition - mind, body, and spirit. Without those dimensions, an alienation process takes place and the individual and social senses are lost. Therefore, emotions define the type and quality of human actions during their social and relational coexistence. For this reason, it is important to work the emotional education in all areas of formal, non-formal, and informal education. Emotional feelings, thoughts, and bodily actions are part of the same phenomenon of inseparable interconnections that form the basis of our socio-ecological relations. If we want to meet the SDG we have to overcome the fragmentation of positivist culture of the twentieth century to understand that all human knowledge is linked to an infinite universe of emotions that shapes our interiority.

In this line of thought, the psychotherapist Claude Steiner postulated the term “emotional literacy” in 1997 to describes the ability to know the emotions, the ability to empathize with the emotions of others, and the art of learning to manage our emotions to solve emotional problems resulting from the interaction with others. According to this view, emotional literacy helps us understand our inner emotional universe with the intention to facilitate relations of social coexistence. We assume the responsibility for our actions by putting emphasis on emotional training of individuals and seeking to improve interpersonal relationships. “An open heart is the foundation of emotional literacy and a prerequisite for the next two stages of emotional literacy training: Surveying the Emotional Landscape and Taking Responsibility” argues Steiner [60: 57], “that is why the training starts here, by learning how to give and take affection – or in plain English, by learning to love.” Educating for emotional literacy is a dual process of personal development and collective activity, i.e., self-development and community building where the sense of welfare grows along with others in a common and shared environment. In that way, emotional education broadens epistemic horizons of ESD to achieve the SDG’ targets, since it seeks to transform entire global citizenship from the root: making them affectively responsible for current ecological and civilizational crisis.

In a school environment, there are different philosophical and pedagogical movements that seek to develop a social emotional learning to train mankind integrally. A good example is the “Waldorf education” postulated by the philosopher Rudolf Steiner in the early twentieth century, which promotes the

physical, spiritual, emotional, intellectual, and artistic development of students with the aim of developing free, socially competent, and morally responsible individuals. Steiner's theosophical training led him to join anthroposophy to education, applying the process of reincarnation in pedagogy to expand the material world into the spiritual world. From this epistemological perspective, Steiner [61: 5-6] explains that "anthroposophy is therefore the knowledge of spiritual man, and that knowledge is not confined to man but is a knowledge of everything which spiritual man can perceive in the spiritual world, just as the physical man observes physical things in the world. (...) The knowledge which he acquires may likewise be called 'spiritual science.'" Thus, the material world merges with the spiritual world in addressing the integrity of the human being. This endogenous development is also present in the perspective of spiritual evolution and material reincarnation of Indian philosopher Sri Aurobindo. "If evolution is a truth and is not only a physical evolution of species, but an evolution of consciousness, it must be a spiritual and not only a physical fact" points Aurobindo [62: 343] while explains "if there is the evolution of a conscious individual, then there must be rebirth. Rebirth is a logical necessity and a spiritual fact of which we can have the experience." According to Aurobindo [62: 35], "through intensity of emotion that the psychic being awakes and there is an opening of the inner doors to the Divine," which means that soul grows during its experience in the evolution of life by experimenting emotions with the purpose to develop its own nature.

Based on these ideas, physicists and philosophers Danah Zohar and Ian Marshall [63: 9] created the concept of "Spiritual Intelligence" (SQ) to refer to the *soul of intelligence*: "SQ is the intelligence that rests in that deep part of the self that is connected to wisdom from beyond the ego, or conscious mind, it is the intelligence with which we not only recognize existing values, but with which we creatively discover new values." For Zohar and Marshall [63], SQ is not culture-dependent or value-dependent - it creates the very possibility of having values in our cultures. Influenced by the Vedanta philosophy of Swami Vivekananda and Mahatma Gandhi, Zohar and Marshall [63: 263] put forward seven practical steps to improve our spiritual intelligence: 1) become aware of where I am now, 2) feel strongly what I want to change, 3) reflect on what my own center is and on my deepest motivations, 4) discover and dissolve obstacles, 5) explore many possibilities to go forward, 6) commit myself to a path, 7) remain aware there are many paths. Taken together, these steps are aimed at making the "spiritual being" be connected to the whole, having the feeling of integrity. In a similar way, the specialist psychologist in interiority, spirituality, and emotional education, Luis López González [64: 47] considers that "interiority is the human *capacity* that allows developing the consciousness of one's self and the environment, giving sense and meaning to the own existence." For this reason, many authors seem to agree that emotional education is a parallel and complementary path to spiritual education and the education of our interiority in the complex processes of human development.

From this multi-referential perspective of our inner universe, it seems clear

that global citizenship cannot meet the SDG without proper training focused on the meaningful learning of emotions, spirituality, and interiority. They all are dimensions of our human condition that must be potentiated to generate sustainable actions. When neuroscience points out that our actions are preceded by neuronal electrochemical impulses caused by emotional feelings and thoughts that arise from our interiority, it can be concluded that we externalize what it is inside of us, and vice-versa, because we also internalize what happens *outside*. This complex process of constant inter-retro-actions between subjects and the environment is an important feature in the co-evolution of living systems. Nonlinear understanding of this emotional order-disorder of our inside-outside universe is essential for those who work with sustainable development. It implies recognizing sustainability as the result reached by global citizenship – a complex adaptive system- in intermediate conditions of order and disorder. Sustainability also is, therefore, an emotional and spiritual issue. So the contributions of emotional and spiritual education are essential for sustainable development and Gaia's care. According to educators Angela Antunes and Moacir Gadotti [65: 143]: “our first education is an emotional education which places us before the mystery of the universe, in close contact with it, creating in us the feeling of being part of this sacred and living creature that is constantly evolving.” In this context of cosmic evolution, Antunes and Gadotti [65] propose eco-pedagogy as the proper pedagogy for the process of the Earth Charter, where it is promoted the emotional feeling of belonging to one common and shared home at the universe: Earth-Homeland.

From a similar pedagogical worldview, educational psychologist Rafael Bisquerra [37] is inspired in the ontological structure of the outer universe to organize the *universe of emotions* of our interiority. In his book *Universe of Emotions* there is a strong *cosmo-mimetic* creativity with rich theoretical contributions to emotional education. While the universe is formed by galaxies, the universe of emotions is composed by families of emotions that Bisquerra [37] metaphorically referred to as galaxies of emotions. They are massive clusters of affective phenomena and the largest structures in which emotions are agglutinated. “It is estimated around 100,000 million galaxies in the universe. Emotions are processed in the brain, where there are estimated about 100,000 million neurons,” explains Bisquerra [37: 21] while arguing “this curious numerical coincidence is another excuse to propose a parallel between the cosmic universe and the universe of emotions processed in the brain.” Analogous to the “wheel of basic emotions” designed by medical doctor Robert Plutchik in his “Theory of Psychoevolution” or the “Circumplex model of Affects” proposed by psychologist James Russell, the “universe of emotions” also represents a didactic, psychopedagogical and psychotherapeutic resource. The universe of emotions is based on knowledge and scientific theories, but Bisquerra [37] recognizes that its configuration is opened to different interpretations due to the intangibility of emotions. In its original sense, astronomy is the science that studies the celestial bodies of the universe (galaxies, stars, planets, satellites, etc.) and is divided into four main branches of knowledge: positional

astronomy, celestial mechanics, astrophysics, and cosmology. In his emotional model, Bisquerra argues that:

*Positional Astronomy* aims to locate the stars in the celestial sphere. It describes the movement of the stars, planets, satellites, and phenomena such as eclipses. The application into the universe of emotions is determining the position of various emotions in space. *Celestial mechanics* aims to interpret the movements of positional astronomy. It studies the movement of the Moon, the planets around the Sun, their satellites and calculates the orbits of comets and asteroids. Its application into the universe of emotions is to analyze the movement to cross from one emotion to another. *Astrophysics* studies the stars as physical bodies, analyzing their composition, structure and evolution. Its application into emotions is to analyze the intrinsic traits of each one of them. *Cosmology* studies the origins, structure and evolution of the universe as a whole (...). Its application to the emotions is to study their origin and primitive functions and their evolution [37: 19-20] (own translation).

With this cosmomimetic vision, Bisquerra [37] defines the epistemological model to create his vision of the emotional universe. The complex universe of emotions is structured in galaxies of emotions that, having similar features and nuances, they are grouped in the same family group. The large spiral galaxies are formed at the top by joy, love, and happiness; while the galaxies of fear, anger, and sadness are in the bottom. The surprise appears as a barred spiral galaxy because it is an ambiguous emotion. Social emotions and aesthetic emotions are elliptical galaxies. In turn, disgust and anxiety are irregular galaxies. Collectively, galaxies form a central prism symbolizing the connection between positive (above) and negative (below) emotions. Emotions belonging to one galaxy are divided into four levels measuring their intensity. “We must make it clear that all emotions are good. The problem is what we do with them. The way we manage them determines the effects they will have on our welfare and on the others,” says Bisquerra [37: 47] adding: “while all emotions have value, some make us feel good and other make us feel bad. Hence some are called positives and other negatives depending on whether or not provide welfare.” While the constellations of positive emotions (joy, love, and happiness) are represented at the top, the constellations of negative emotions (fear, anger, and sadness) are at the bottom. The existence of these two constellations represents our emotional polarity: joy-sadness, love-have, etc. In the emotional intergalactic space are located the values and attitudes for their implication in the affective states that embody our actions. Here lies the importance to understand how “universal values” emerge from the emotional feelings of our inner universe. If a human being did not have the ability to feel emotions would be a psychopathic species incapable of understanding the planetary emergency of current unsustainability. In fact, this is what happens with large corporations at the transnational level [50]. They are entities with-

out conscience or emotional feelings that are guiding the course of humanity towards climate catastrophe in their insatiable desire for economic profit. For this reason, sustainability must be conceived as a complex and interdependent process that spans multiple cosmic, ecological, political, economic, epistemic, emotional, and spiritual dimensions.

From this perspective of sustainability, it is so important to know the cosmic universe as well as our inner emotional universe. While the knowledge of a cosmic universe allows us to assess the emergence of life in the Big History as an exceptional event that we must preserve and conserve at all costs; the emotional knowledge of our inner universe allows us to improve the quality of our relations with other people and with nature. Therefore, walking towards sustainability means setting the emotional course for our mental, social, and environmental welfare. We cannot let the markets of economic globalization continue managing the civilizing course because it has a huge negative impact on our personal health and the planet's health. The great transition to "other possible worlds" is a twofold process of internal and external transformation of our human condition that requires new transdisciplinary educational models aimed to create strong links between emotions and the environment. This symbiosis represents the ideal mindset for the emergence of a cosmodern education that allows us to improve our human ability to learn how to co-evolve in harmony with all ecosystems of nature.

Emotional learning has a key paper to respect the *Pachamama* (our Mother Earth according to the indigenous cultures of the Andes) and to achieve the SDG. When the emotional and socio-ecological pedagogical practices are integrated, it is possible to plant the seed of sustainability in every human being: stimulating their self-esteem to improve their social skills and develop healthy lifestyles for our planet. As demonstrated by neuroscience, emotional feelings precede our actions, which means that before learning to inter-retro-acting sustainably we must learn to feel in harmony with nature. It is for this reason that sustainable development can not be reduced to just three dimensions (social, economic, and environmental), as happens in almost all statements of the UN system. This reductionist view does not allow us to internalize the complex phenomena that are inter-retro-acting constantly in the *continuum* of life during its co-evolution with the environment. As it has been demonstrated in this study, our emotions, spirituality, and interiority are a fundamental dimension for the achievement of the SDG through a comprehensive and sustainable human development. For this reason, "before a child learn the alphabet and some notions about the world, should learn what is the soul, truth and love, and what forces are sleep in the soul," explains pacifist activist Mahatma Gandhi [66: 100], arguing that "an even more essential part of education should teaching child to win the battle of life to conquer hatred with love, falsehood with truth, and violence with his own suffering." In the educational philosophy of *Gandhiji* (as he is popularly known in India), love is a feeling that fights against violence to be a law of truth and life. What is the role of love in the future we want?

## 18.9 Final Conclusions for the Future We Want

SDG have an important role in Big History because the human race has had a profound impact on the climate and environment of the Earth. They represent our last opportunity to avoid ecological extinction and points of no return in the new geological era we have entered – the Anthropocene. This period is characterized for the great human footprint on Earth, causing a huge extinction and dramatic environmental degradation. Reflecting on challenges concerning the SDG carries many questions and approaches. Therefore, the transdisciplinary and biomimetic contribution of this study has to be understood as a proposal to raise the consciousness in evolution, opened for new re-interpretations, additions, and considerations. I believe that emerging global citizenship must learn to contextualize human history, life history, history of Earth, and the history of the universe from transdisciplinary methodological approaches. This involves examining the multidimensional identity of the emerging planetary citizenship through a cosmodern approach that views the complexity of the human condition as an *individual-society-species*: contextualizing cosmo-biologically the human *species* to understand we all are ontologically equal beings (with the same molecular composition of DNA); with a rich cultural and spiritual diversity that characterizes every *society* in terms of their phenomenological and hermeneutical historical context; and with interests, motivations, and dreams radically different between *individuals*. A human condition is, moreover, interconnected in the *cyber-space-time* through mobile devices in its virtual identity condition. This cosmodern vision that contextualizes our human condition in a multidimensional way supposes a true educational transformative tool to promote a new mindset where we all are ready to *feel-think-act* in harmony with nature. In short, this cosmodern philosophy is the epistemic training of authentic *worldlists*, an expression created by the Argentine writer Ernesto Sábato to argue the great need of our planetary civilization to have people who are taking care of the most urgent and global problems of the world. In this sense, love is the most powerful energy to transform our world-society.

For this reason, we have to implement this transdisciplinary and biomimetic vision in all pedagogical contexts of schools and universities to strengthen the links between education and sustainability. This cosmodern mindset promotes the creation of new socio-economic models with planetary character to feel-think-act in harmony with co-evolutionary processes of nature. Biomimicry is a meeting point between the societies called “primitive” and the so-called “hyper-technological” because it has a spiritual and ecological corpus playing the symbiogenetic role between nature and human culture. Thus, the past and the future are present in the spiritual and scientific research process, complementing a common reality shaped by the undivided wholeness of consciousness, matter, and energy [67]. “Just like transdisciplinarity, biomimicry-inspired problem solving, with a deep emphasis on how humans from all walks of life can learn from nature, focuses on the processes and energy flows inherent in

deep, complex interactions among people's internal world and their external world, mediated by such factors as culture, art, religion, and spirituality", said McGregor [7: 63]. Transdisciplinary refer to the latter as the Hidden Third, the place full of potential where people's experiences, interpretations, descriptions, representations, images, and formulas meet. Then, we have to combine a framework of convergence between scientific knowledge that our outer physical universe offers us, with the spiritual wisdom of the inner emotional universe of mankind [68]. According to Núñez [36], the ancient philosophical traditions of indigenous peoples show us that psychosomatic experiences between the body and the mind help us to establish and develop sacred connections between Nature and Life – promoting sustainable human habits with the environment. A good contemporary example that seeks to rescue such millenary knowledge and wisdom of the Aboriginal peoples of Australia is the permaculture created by the scientist David Holmgren [69].

In current context, SDG educational strategies of Action Framework for 2030 should seriously reflect on the possibility to build a great human family through a cosmodern consciousness that identifies our human condition within co-evolutionary processes of Big History. In abstract, it is necessary to foresee the future to be ready when it arrives, because there are not doubts that nanotechnology, quantum computers, artificial intelligence, contact lenses with internet access, genetic mutation of DNA, and space travels will radically change our human habits in a short period of time. That is why we must train global citizenship for the emerging Cosmodern paradigm [70: 105]. It has come the time to walk together to the challenges of this new civilizational paradigm following the African proverb that says, "If you want to go fast, go alone. If you want to go far, go together." Are you ready? I invite all readers to move forward with any thought inspired by the transdisciplinary and biomimetic ideas of this work for the fulfillment of the Sustainable Development Goals.

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# CHAPTER 19

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## Communicative Action and the Transdisciplinary Education in Taiwan

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Based on the theory of communicative action developed by the German sociologist Jürgen Habermas, we performed a systematic review of the development of Trans-Disciplinary Education in Taiwan. The development of Trans-Disciplinary Education in Taiwan is initiated by MOE Program for Trans-Disciplinary Education on Society-Humanity-Science and is also abbreviated as SHS Program. There are three sections in this paper. In the first section, we explained the SHS Program and its organizational framework. We examined then the theory of communicative action and discuss why his theory is adopted in this study. In the final section, we reviewed a plan of ten discussion topics with communicative action to illustrate how the SHS program mobilizes the faculty members to participate in public affairs. Since this program is still in progress, we are following four essential guidelines to describe the development of the Trans-Disciplinary Education in Taiwan.

**Keywords:** Communicative action, Transdisciplinarity, Trans-Disciplinary education.

### 19.1 Introduction

**Trans-Disciplinary Education Program Office, MOE, Taiwan** – The program of Trans-disciplinary Education was launched in 2012. As a pilot project [1] of the Ministry of Education in Taiwan, this program is officially titled “MOE Program for Trans-Disciplinary Education on Society-Humanity-Science – Cultivation for the Competence of Cross-Boundary Problem-Based Learning in Colleges”, and is abbreviated as SHS Program[2].

**Why did the SHS Program adopt the idea of Transdisciplinarity?** – The term “transdisciplinary” is defined in different ways internationally. The academic debate on transdisciplinarity in the context of higher education refers to the “Seminar on Interdisciplinarity in Universities” in 1970. This seminar was critical in drawing outlines for transdisciplinarity [3, p. 18; 139, 4, pp.46-47]. Centre for Educational Research and Innovation was the organizer of this seminar. The starting point was to get a better understanding of the following problem: “how to unify knowledge and what the many implications of such unity are for teaching and research in the universities” [5, p. 11]. A group of distinguished authors, such as Heinz Heckhausen, Marcel Boisot, Erich Jantsch, and Jean Piaget reflected on the idea about how the purpose of teaching is deeply tied to the previous academic disciplines. Therefore, interdisciplinarity represents methodological guidelines to unify fragmented knowledge, which usually is dispersed in different academic disciplines. Scholars, such as Heckhausen, Boisot, Jantsch, and Piaget, tried to set up general principles to re-categorize (regroup) disciplines by clarifying terms such as multidisciplinary, interdisciplinarity, and transdisciplinarity. In other words, they gave themselves an exceptional task to redefine “a common system of axioms for a set of disciplines” [6, p. 515].

The Swiss developmental psychologist, Jean Piaget, pointed out that the idea of interdisciplinary and transdisciplinary will become clear when people carry out a study with cross domain perspectives. Piaget addressed the epistemological pathway from the biological and social domains to science in general [7]. Inspired by Piaget, Erich Jantsch asked about the purpose of science and criticized that science is preserved as a ‘value-free’ abstraction. Compared to multidisciplinary and interdisciplinarity, Jantsch ascribed systemic thinking to transdisciplinarity. He proposed to use transdisciplinary thinking to promote organizational reform and innovation in universities, which was called ‘transdisciplinary university structure’. In his opinion, while the university is a political institution, on the top of this structure should be the purposive level. Thus, the central theme of transdisciplinary approach should be understood as the new ‘univeristas’ as it would be oriented toward humanity [8, pp. 114-121].

After three decades, this idea of transdisciplinary university structure is also found in the “Handbook of Transdisciplinary Research”:

*“Transdisciplinary orientations in research, education and institutions try to overcome the mismatch between knowledge production in academia, and knowledge requests for solving societal problems”.*  
[9, p. 3]

SHS Program aims at identifying approaches to Cross-Boundary Learning and research, while maintaining the training program as an educational platform for both teachers and students to engage in local and global issues. Hence, the SHS Program adopted the concept of “transdisciplinarity”.



Figure 19.1: Organizational framework of SHS Program.

### 19.1.1 Organizational Framework of This Project

This four-year SHS program is implemented through the operation of five subdivisions (see Figure 19.1):

- (a) *Promotion Office for Curricular Innovations in Trans-Disciplinary Education* – This office serves to review and evaluate transdisciplinary curricula and training programs developed by colleges nation-wide. In addition, this office responds to request for curricular innovations and practices in terms of transdisciplinarity and problem-based-learning. The expected results should be having courses and clusters addressing major issues of Taiwanese Society.
- (b) *Office for Internet Multimedia Service and Communication* – This office serves to produce program outcomes through internet and communications.
- (c) *Master Academy* – A one-week summer academy aims to set up an internationally known learning arena for Trans-Disciplinary Education. Students and teachers will be inspired and trained with the approach of “learning by doing” through competition and interactive training.

- (d) *Regional Promotion Centers* – The promotion centers are responsible for cross-school and cross-region activities, including workshops, symposiums, and competitions.
- (e) *Office for Teaching and Learning Development within Trans-Disciplinary Education* – This Office aims at providing faculty members to have an in-depth understanding of trans-disciplinarity for curriculum design. To facilitate the professional development objective, this office organizes workshops and publishes a self-learning digital book. Through the workshops and discussions, participants will improve their skills in course design and curricular innovation[2].

### 19.1.2 The SHS Program Runs by Platforms

The program office and the five sub offices were established through the Request for Proposal (RFP) [10]. According to the Guidelines for Pilot Project under Humanity and Technology Education [1], SHS Program must be innovative, experimental, and fulfilling the following tasks:

- It should have positive impacts on higher education and establish models for training programs for scientific and technological talents.
- It should provide guidance for teaching and research in related fields.
- It should contribute to international interactions in the field of education and enhance academic reputation of Taiwanese Universities.
- It should establish a platform to integrate teaching and research resources and to share the resources.

From an administrative point of view, the existing multidisciplinary, interdisciplinary, and transdisciplinary programs can be divided into two categories:

1. Programs organized within universities: the University Strategic Research Groups in the University of Southampton, the Interdisciplinary Studies Field Major at UC-Berkeley, the MA Transdisciplinary Studies in Zurich University of the Arts, etc. [11, pp. 174-181].
2. Programs run by national or international organizations: “Network for Transdisciplinary Research” (TD-NET), “The Academy of Transdisciplinary Learning & Advanced Studies” (TheATLAS), and the “International Center for Transdisciplinary Research” (CIRET). These Organizations serve as the platforms for other existing organizations. They focus on particular central themes like sustainability and urban design[12] in initial phases [13].

With the experimental aspect, the SHS Program begins its platform in the universities in Taiwan and then opens to public issues that help establish the concept of transdisciplinarity. In addition, it uses a top-down approach to

introduce transdisciplinarity as an educational concept in the field of higher education. While SHS Program transforms the big picture of Transdisciplinarity to the operational details under bureaucratic practice, it uses Communicative Action to define the program's orientations, objectives, and proposals.

## 19.2 Necessity for Communicative Action in SHS Program

SHS program emphasizes Transdisciplinary Education, while the existing academic disciplines are the foundation of the knowledge for teaching purposes in universities in Taiwan. The excessive usage of buzzwords in recent years has caused a skeptical suspicion on the legitimacy of popularizing Trans-Disciplinary Education in the field. While hoping to promote the concept of Trans-Disciplinary Education, the officials in the higher education worry that Trans-Disciplinary Education would remain an abstract buzzword with no real impact. Transdisciplinary represents knowledge intermediation and communication, which is beyond the existing disciplinary boundaries [14]. That is to say, when we integrate our thinking with knowledge in existing disciplines, we are not able to describe clearly the process of transdisciplinarity. It becomes a concern that without discussions about epistemological or methodological understanding, the concept of Trans-Disciplinary Education would be used in any given situation and eventually lose its value.

Jürgen Habermas's concept and theories are appropriate to illustrate this concern. In his Theory of Communication, Habermas<sup>1</sup> pointed out the social theoretical distinction between the life-world and the System. He strongly criticized the uncoupling of System and Life-world, and the "commodification, bureaucratization, and colonization of the life-world". In his view, the systems become increasingly complicated in modern life. Therefore, the life-world turns out to be increasingly rationalized. In this process, system mechanisms gradually become detached from the social structures and developed into "autonomous organizations". Finally, these autonomous organizations uncoupled from the life-world. They are connected with one another via delinguistified media of communication such as money and power. The social interaction is steered by these systemic mechanisms and disconnected from cultural norms and values. In the meantime, the life-world becomes a subsystem – a part of the whole social system. Therefore, the systemic mechanisms must be closely related to the life-world. This means that they need to be institutionalized in

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<sup>1</sup>The German social philosopher Jürgen Habermas, born in 1929, belongs to the second generation of critical theorists, the so-called Frankfurt School in Germany. His idea of critical theory, discourse ethics and legitimacy crisis are very important to analyze the contents of the social practices, also the education policy in advanced capitalist societies. 15. Shapiro, S., Crisis of legitimation: Schools, society, and declining faith in education. *Interchange*, 1984. 15(4): p. 26-39, 15. Ibid., 16. Thomassen, L., Habermas: a guide for the perplexed. 2010, New York, USA: Continuum, 16. Ibid., 17. Terry, P.R., Habermas and Education: knowledge, communication, discourse. *Curriculum Studies*, 1997. 5(3): p. 269-279.

the modern societies [18].

Habermas believed in the idea of legitimation central. His theory of legitimation crisis focuses on the topic of the fundamental crisis tendencies in the modern, liberal, and democratic welfare state. Habermas believed that the fundamental problem of the modern capitalist state and the most obvious threat to their survival is the tendency to develop a legitimation deficit [19]. In Habermas's view, this deficit in capitalist society may be due to the Repoliticization of the public sector. That is to say, the state expands its activities immensely in the areas of economic and social life of citizen. The activities include more subdivisions such as our rationality of administrative planning and values of political community [15]. The rationality of administrative planning furthers the politicization of the private sector in our life, such as education, especially curricular planning. This tendency endangers the civil privatization that's essential to the de-politicized public realm [20, pp. 369-370]. Therefore, the legitimacy of policies such as educational reforms also needs to be addressed. The program, Trans-Disciplinary Education, for example, is a part of a mid-term plan of MOE. To promote this plan, the promoter would need to constantly reflect on this essential question: how do I know that transdisciplinary thinking brings us a new vision, but not a collective delusion in our minds? We need research to find out the best ways to confirm it. By giving clear and concrete explanations to MOE's mid-term plan, we might be able to help answer the question. Finding out the context of trans-disciplinary program development and its operable parts would be the first step. The following step would be to test the program's rationality and feasibility. Therefore, this article is meant to deal with the following issues: the relationship between the development of transdisciplinary thinking and higher education, the focus of important domestic and international events relating to transdisciplinary thoughts, and the reasons why a person involves in promoting transdisciplinary thinking.

Another rationale that the authors use Habermas' theory is that it provides a theoretical base for the perception of planning. It emphasizes a widespread of public participation - sharing of information with the public, reaching consensus through public dialogues rather than the exercise of power, avoiding privileges of experts and bureaucrats, and replacing the model of technical expert with the reflective planner [21-26].

A pilot project of Ministry of Education has a mission - to initiate necessary reforms for higher education policy. According to Habermas' theory of discourse ethics, the "validity claims"<sup>2</sup> are redeemed in "discourse", or communicative action. This means that all communication is open to being tested as to whether it is comprehensible, sincere, truthful, and appropriately expressed [27, p. 7].

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<sup>2</sup>Validity claims are the assumptions that we always already make in an unquestioning manner concerning the truth and sincerity of other's communications. This questioning of assumptions underpins not only the traditional sciences but also social sciences. 27. Murphy, M. and T. Fleming, *Communication, Deliberation, Reason in Habermas, Critical Theory and Education*, M. Murphy and T. Fleming, Editors. 2010, Routledge: New York. p. 3-16.

“The goal of coming to an understanding ‘*Verständigung*’ is to bring about an agreement ‘*Einverständnis*’ that culminates in the intersubjective mutuality of reciprocal understanding, shared knowledge, mutual trust, and accord with one another. Agreement is based on recognition of the corresponding, validity claims of comprehensibility, truth, truthfulness, and rightness” [28, p. 3].

Habermas’s intention was to establish a theory concerning communication as a way to reach a shared understanding. For the purpose of developing a shared understanding, the speaker and listener must, in Habermas’s view, agree to the universal validity of the claim raised in the process of communication. Potentially, the listener could challenge these validity claims. The validity claims were deemed accepted by the listener when the listener accept a speech act [29]. In summary, good communication is necessary in order to reach a consensus.

SHS Program, as a pilot experimental project of MOE, involves many stakeholders, such as all the faculty members in Taiwan. However, these stakeholders are not “guinea pigs” in this experimental project. Therefore the “validity claims” of SHS Program must be redeemed. This means that the approaches to defining orientations, objectives, and proposals for trans-disciplinary education can be identified and agreed so that these needs could begin to be included in public policy.

A third reason, from Habermas’s communicative action, one sees the possibility of a connection to social capital. Communicative action is an individual action designed to promote common understanding in a group and to promote cooperation, as opposed to “strategic action” designed simply to achieve one’s personal goals [30, pp. 85-101, 284-288].

The next section is a case report for the process of promoting cooperation via communicative action. SHS Program organized a convention called “0.com activity” of Master Academy with an intention to obtain a methodological guideline for transdisciplinary education in Taiwan.

### **19.3 Approaches to Communicative Action in SHS Program**

In the late sixties of the twentieth century, John Platt [31] recruited a large-scale of scientists to solve problems caused by crisis in United States. He explained and classified the problems in the following categories: total annihilation, great destruction and change, widespread almost unbearable tension, large-scale distress, and tension producing. Table 19.1 illustrates some cases under his classification of problems and crisis.

Erich Jantsch expressed his concern in reference to Platt’s approach to organizing scientists:

*“A certain danger may be seen here in the temptation to take a straightforward problem-solving approach of the type which has*

**Table 19.1:** Classification of problems and crisis in John Platt's exposition.

Estimated Crisis Intensity	Problems
Total annihilation	Nuclear or RCBW escalation
Great destruction or change	
Widespread almost unbearable tension	Administrative management Slums (the gap between rich and poor Racial conflicts
Large-scale distress	Transportation Crimes
Tension producing	Cancer and heart diseases Smoking and drugs Artificial organs Water supply shortage Marine resources Internet privacy

*proved so successful in attaining purely technological targets, and to neglect the systemic character of most of these problems in the social area” [8, p. 99].*

Jantsch reminded us that the topics about meanings and values should be the first priority in the academia field.

The architects of the SHS Program were aware of this blind spot in a straightforward problem-solving approach. To figure out the guidelines for proceeding transdisciplinary education as a reform movement, the director of the SHS program conducted a forum to inspire reflections among experts in various fields across humanities, social sciences, and natural sciences - philosophy, chemistry, physic, electrical engineering, geography, anthropology, sociology, biology, literature, history, psychology, mathematic, etc.. This event in the year 2011 is called “0.com activity” of Master Academy and lasted for two days.

In the “0.com activity” of Master Academy, over 50 local scholars and scientists were invited. In the invitation, the scholars were asked not only to identify the most important issues for people in Taiwan, but to elaborate the meanings and values of those topics. The four validity claims addressed by Habermas, namely comprehensibility, truth, truthfulness, and rightness were therefore fulfilled. The “0.com activity” of Master Academy provided a forum where participants voiced concerns about critical local and global issues and made efforts to establish a mutual understanding on the issues. The *Discourse on the Origin and Basis of Inequality Among Men* developed by

Jean-Jacques Rousseau was one of the central themes in this event. Hence, further discussions about values and meanings were facilitated in the forum.

The “World Café” approach developed by Juanita Brown and David Isaacs [32] was applied in the event. Collaborative deliberations between nature scientists, social scientists, philosophers, and other humanities took place at the event. The discussions were aimed at identifying critical issues relating to local conditions in Taiwan. Ten main topics took shape from the discussions, vote and modifications:

### **Topic I: Academic Freedom and Globalization**

Currently, academic development in Taiwan is confronted with a conundrum between its autonomy and globalization. This topic explored issues with the following guiding questions:

- What are the phenomenons under the conundrum between academic colonization and academic autonomy?
- How were the problems formed? How should we confront the problems by establishing a new academic paradigm to meet the needs of Taiwanese society?
- What are universities’ roles in training scholars to be equipped with skills to handle global challenges?

### **Topic II: The Paradigm-Shift from Knowledge-Based to Literacy-Based Curriculum in Taiwanese Higher Education**

Under the educational reform, the higher education in Taiwan has shifted its curriculum focus from knowledge-based learning to literacy and practical wisdom-based learning. This topic discussed the following:

- What causes such curriculum shift?
- What are the differences between knowledge-based and literacy-based learning?
- What is practical wisdom? How to teach it?
- How should we develop curriculum and design activities to promote practical wisdom?

### **Topic III: Issues of Democracy within a Multi-Cultural Society**

As democracy grows, Taiwanese society has encountered various issues and conflicts. This topic explored the following questions:

- What causes conflicts and hatred in a society?
- What is the impact of conflicts and hatred to a society?

- How to resolve conflicts and hatred?
- Is having tolerance and acceptance enough to maintain justice and harmony within a society?
- Besides being tolerant, what are other personality traits that are probable to improve communication and decrease conflicts?
- What are the university's roles in resolving such issues?

#### **Topic IV: Emerging Issues of Societal Innovation**

As the society grows, expands, and progresses, Taiwan has stumbled upon various problems during this process. This topic discussed the following:

- What is the bottom line as a democratic country developing its political structure to promote free market and nationalism?
- Will the same political structure exist in the future societies?
- If new political structure is demanded, what will it be? Why?
- What are university's roles to facilitate resolutions of these issues?

#### **Topic V: Concerns with Eco-Innovation and Sustainable Development**

This topic discussed issues around economic development in Taiwan with following questions:

- What is happening with contract manufacture in Taiwanese industries?
- How is relying on contract manufacturing affecting long term business and industrial development in Taiwan?
- Why is improving Taiwanese companies' research and development capability the best approach to enhance their competency?
- How could universities support in training elites to help reach the industrial goal of enhancing companies' research and development capacity? Are there other approaches to accomplish this goal?

#### **Topic VI: The Issues of Demographic Change**

Taiwan is facing demographic changes with its population. This topic explored the following:

- What are the concerns of aging population, declining birth rate, and new immigrants in Taiwan?
- How could technology be effective in resolving these concerns? What are other resolutions?
- What are universities' roles in providing solutions to issues caused by demographic changes in Taiwan?

### **Topic VII: The Issue of Natural Resources Depletion and Appropriate Usage of Natural Resources**

We are encountering challenges caused by the worldwide natural resources depletion. This topic discussed the following:

- What are the problems of water resources in Taiwan?
- What are possible solutions to water shortage? Why?
- What are universities' roles to help resolve issues of water shortage?

### **Topic VIII: Issues of Technology and Social Symbiosis**

The development of high technology has brought both positive and negative effects to Taiwanese society. This topic explored the following issues:

- What are the negative effects caused by the usage of high technology in our daily lives?
- What would possible limitations be for high-tech usage in the future?
- What are the negative environmental effects caused by the development of mass transportation in Taiwan?
- How should we resolve as well as preventing the potential environmental damages as high technology continues to evolve as the society grows?
- What are universities' roles in responding to the issues caused by technology?

### **Topic IX: The Issues of Cultural Identities**

With the unique historical development, Taiwan has gone through various challenges under cultural identities. This topic discussed the following:

- What are some cultural identity concerns faced by people in Taiwan?
- What are the differences between cultural identity and national/political identity?
- What are some methods to resolve conflicts raised by cultural differences?
- What are universities' roles to manage the needs in dealing with recognizing cultural differences and identity issues?

### **Topic X: The Issue Between Individualism and the Value of Collectivism**

As life evolves, we experience constant change every day. The practice of individualism and collectivism sometimes contradict each other. This topic will explore the following:

- What is justice? What does being fair mean?

- Why does the meaning of justice and fairness change in different societies and different historical time periods?
- What is the impact of having the value of justice and fairness to human society?
- How could we encourage people to embody individualism as well as collectivism and pursue the happiness of justice and fairness?
- What are universities' roles in response to the issue of lacking the value of justice and fairness?

These ten important issues exhibit a rationale and illustrate the reasons why transdisciplinarity is needed in higher education in Taiwan. After this event, the SHS program office conducted the Request for Proposal (RFP) process to recruit faculty members nationwide to run the sub offices of the SHS program. The director of Promotion Office for Curricular Innovations in TDE and the project director of the Master Academy were the participants in “0.com activity” of Master Academy[Trans-Disciplinary Education Program33].

The Promotion Office for Curricular Innovations also steered the RFP process to enlist higher education faculty members who need sponsorship for running their transdisciplinary training programs. So far, the Promotion Office has sponsored 54 projects for curriculum innovation within transdisciplinary education. Moreover, faculty members from 68 universities in Taiwan have also expanded their proposals. By introducing their transdisciplinary curriculum, the candidates also discussed the topics that they wish to design in their transdisciplinary training programs. Some projects are more comprehensive and covering more topics than others. Most teachers involved in transdisciplinary training programs expressed interest in the issues relating to natural resources depletion and appropriate usage of natural resources, technology and social symbiosis, concerns with eco-innovation and sustainable development, and demographic change. Figure 19.2 shows the breakdown of interest shown in each topic in the RFPs:

In the proposals, there were courses related to philosophical propositions, such as truthfulness, righteousness, and beauty being proposed. They were identified as “other issues” by different programs. Among the 54 projects, five of them are much more well organized than the rest. They provide real-world problem-oriented course clusters with more than 20 courses for each cluster to their participants. Each course cluster focuses on one of the particular issues - “impact of global change on people in Taiwan”, “appropriate usage of information technology”, “aging population society”, “rural regeneration”, and “marine resources depletion”. The authors have concluded that the success of these five projects is due to a better administrative support in curricular innovation and modification by a university or an interdisciplinary research center operated in a university.

The Program Office also invited participants (see Figure 19.3) to serve as consultants to evaluate the execution of the SHS Program, especially the

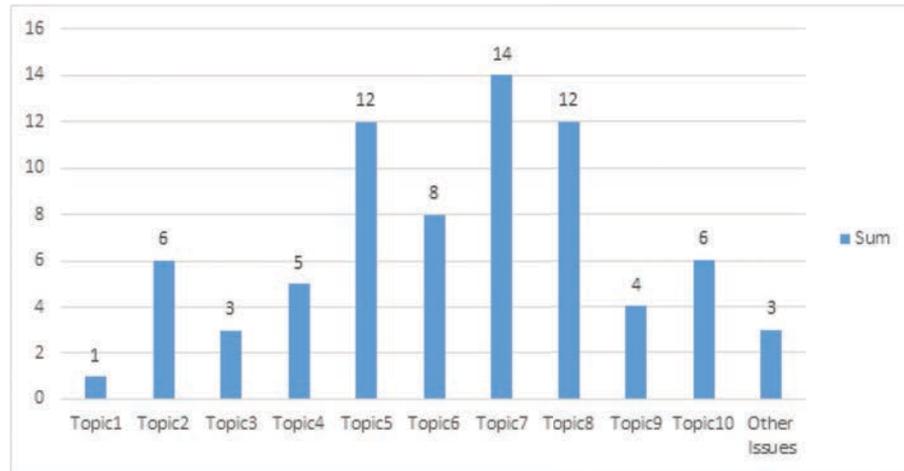


Figure 19.2: Most important issues identified in the transdisciplinary training programs in Taiwan.

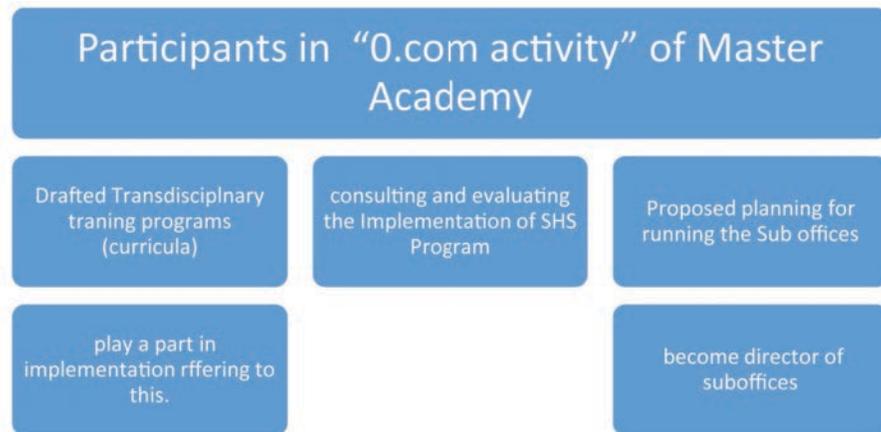


Figure 19.3: The subsequent contributions of the participants in “0.com activity” to SHS program.

implementations of the sub offices and the transdisciplinary training programs. These participants have become the core group to provide support to the transdisciplinary education movement in Taiwan. Figure 19.2. The subsequent contributions of the participants in “0.com activity” to SHS program.

## 19.4 Conclusion and Future Goals

This intellectual collaboration in “O.com activity” has not only helped transform Transdisciplinarity from the big picture to the operational details, but also facilitated improvement in curriculum development and design. It was also valuable for the pragmatic development of teaching materials and teaching methods regarding to transdisciplinary (sciences, humanities and social) implication. Also, the goals for the SHS Program to fulfill the validity claims were met:

- **Sincerity:** The “O.com activity” served as a palpable exemplar for collaborative inquiry. Scholars in the field of academia established a mutual understanding about knowledge integration. In terms of sincerity, the participants shared a common objective to build mutual trust for openness. Hence, a collaborative inquiry was able to make headway and recognize common principles of humanity. The SHS Program provides an importance to the social awareness for the students.
- **Comprehensibility:** It is necessary to integrate professional literature with general literature by drafting a transdisciplinary curriculum. The SHS program aims at training students to enhance their oral expression so that knowledge transfer could be fulfilled by experts from various disciplines.
- **Rightness:** The participants were willing to take part in knowledge integration with the collective intelligence aiming at achieving common good. With regards to curricular contents, it was recognized that the transdisciplinary training programs should be real-world- problem-oriented. Furthermore, the collaborative inquiry should also be introduced in the path of teaching and learning.
- **Truth:** The participants employed realistic propositions to identify the most important issues in Taiwan and their possible solutions. By sharing their professional diligence, the participants were devoted to factually valid arguments. Thus, Transdisciplinary Education is deemed to focus on teaching and researching, extending the concept of the “Flipped classroom” [34], and developing alternative methods for teacher-student co-learning in the various disciplines in universities.

The SHS Program applies the theory of transdisciplinarity with the goal to train students to employ trans-disciplinary thinking when solving problems. Moreover, the training program serves as an educational platform for both teachers and students to engage in critical local and global issues. Therefore, another objective of the SHS program is to educate students to conduct transdisciplinary research which is “frequently associated with pragmatic or solution-oriented research” [12]. However, as the project unfolds, the authors have detected potential challenges of implementing transdisciplinary education in Taiwan.

First, based on the existing examples of communicative action in “0.com activity”, transdisciplinary education advocates collaboration among intellectuals in the field of higher education. In spite of the positive outcome in the event “0.com activity”, the authors still ponder about ways to optimize the other sub offices, like Regional Promotion Centers, to help teachers, students and build and maintain cohesive transdisciplinary teams and put their projects into practice.

In regards to Habermas’s communicative action, scientific knowledge alone cannot explain everything [12, p. 479]. The “0.com.activity” is therefore just the start point of transdisciplinary education movement, otherwise the SHS program represents only a case of elitism [35, pp. 1-4]. To fulfill the objective of transdisciplinary research, the training programs need to involve various stakeholders outside the academia as reviewers in their projects. With impartial perspectives, the training programs hope to bring their students’ to research results to optimal fruition.

The SHS program in Taiwan continues to grow. The goal for the next phase is to collect data on students’ performance after being trained in transdisciplinary thinking. Inspired by TED Talk<sup>3</sup> that puts forth a great influence worldwide, the SHS program employs an unconventional method to show students’ performance. The program promotes SHS Talk to offer a forum for teachers and students in the SHS program to share their results of transdisciplinary research in the form of public speaking.

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<sup>3</sup>TED stands for technology, entertainment, and design 36. Donovan, J., *How to Deliver a TED Talk: Secrets of the World’s Most Inspiring Presentations*. 2013, New York, USA: McGraw-Hill.. 36. Ibid.

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## About the Author



**Dr. Kung-Pei Tang** is an Assistant Professor in the Center for General Education at Taipei Medical University. In 2011, Kung-Pei received his PhD of School Education at University of Würzburg in Germany. From 2012 to 2014, he worked as postdoctoral research fellow for the Trans-Disciplinary Education Program Office at National Taiwan University. In this program, it is expected that with such transdisciplinary learning path, students will be able to adopt inquiry thinking and hands-on experience with pluralistic perspectives, particularly with engagement in learning to solve critical local issues. Since then he is devoted to identify useful didactic strategies for facilitating transdisciplinary learning.

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## About the Editors

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**Dr. Atila Ertas**, Professor of Mechanical Engineering, received his masters and Ph.D. from Texas A&M University. He is a Senior Research Fellow of the IC<sup>2</sup> Institute at the University of Texas Austin, a Fellow of American Society of Mechanical Engineers (ASME), a Fellow of Society of Design and Process Science (SDPS), and a Fellow and honorary member of The Academy of Transdisciplinary Learning & Advanced Studies (TheATLAS). He is also an honorary member of International Center for Transdisciplinary Research (CIRET), France. Dr. Ertas has earned both national and international reputation in engineering design. Dr. Ertas is the author of a number of books, and technical papers that cover many engineering technical fields. Dr. Ertas' contributions to teaching and research have been recognized by numerous honors and awards. He has been PI or Co-PI on over 40 funded research projects. Under his supervision 194 MS and Ph.D. graduate students have received degrees.

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