Transdisciplinary & Interdisciplinary Education & Research

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Preface

This book presents a wide variety of contributions, coming from authors located in the Unites States, various European countries, Mexico and New Zealand. In terms of the content, the chapters may at first glance look to have little in common, as they touch upon a wide range of topics such as the United States Petroleum Industry, inter-disciplinarity in the academic environmental sector in Mexico, photosynthesis, the philosophy of transdisciplinarity, sustainability as art, scientific collaboration, aesthetic experience, the Indian sacred book Atharva-Veda, decision-making processes and more. Nevertheless, there is common ground in all of them. The message in almost all chapters is that transdisciplinarity is not a recent invention or a novel concept referring to a new practice. On the contrary, transdisciplinarity basically always existed – as a practice - in science, in art, in indigenous cultures as well as in decision-making process. Transdisciplinary knowledge production is not something that we need to create, but that we rather need to recognize and work with in knowledgeable and educated ways.

Many authors in this book show us the existence of transdisciplinarity, in places where we easily overlook, or ignore, its presence. Larisa Kiyashchenko, Sarah Gehlert et al., Ulli Vilsmaier, Vera Brandner and Moritz Engbers, Mambet Cantemir, Zoltán Baracskai and Viktor Dörfler, Anthony Cole, Anne Bationo, Francesca Cozzolino and Hans Dieleman all present us with this challenge of recognizing the existence of transdisciplinarity where we usually are not aware of it. A next step is to knowingly work with the phenomenon of transdisciplinarity, learning to handle its immanent complexity, and relearning to be transdisciplinary, in educated ways. Various authors make concrete proposals in this respect, like Sacha Kagan, Samuel Bianchini, Paulo Nuno Martins, and again, Larisa Kiyashchenko, Ulli Vilsmaier, Vera Brandner and Moritz Engbers, Mambet Cantemir and Zoltán Baracskai and Viktor Dörfler. Others show us the need for research and education, both in inter- as well as in transdisciplinarity, not only for epistemological reasons, but equally because contemporary society and economy asks for this kind of knowledge. These appeals can be found in the chapters of Christopher Kreger, Daniel Moran and Stacie Therson, María Concepción Martínez Rodríguez, Luis Ángel Jimnez López and Omar Mayorga Pérez, Jerome Moore and Adam Hines, and again, Anthony Cole and Paulo Nuno Martins.

Larisa Kiyashchenko, in her chapter "*Philosophy of Transdisciplinarity: Approaches to the Definition*" explores transdisciplinarity as a way of knowing that surpasses the boundaries of academic versus practical knowing, as it equally surpasses the dichotomy of universal versus particular knowing. Transdisciplinary knowing involves a wide range of practical, religious and other experiences, all required for dealing with societal problems. This wide range of sources co-shape our disciplinary knowledge, vise versa, thus creating knowledge in spaces beyond both science and mere practice. Therefore, Larisa argues, the philosophy of transdisciplinarity has an incomplete, procedural nature, and the style of philosophizing is developed in three main transpositions: of the observer, the participant and the witness.

Sarah Gehlert et al., in their chapter "*The Structure of Distributed Scientific Research Teams Affects Collaboration and Research Output*" touch upon comparable ground, albeit in a very different way. They studied collaboration in scientific teams in biomedical research, more in particular in funded projects carried out in cross-disciplinary collaboration by researchers located in multiple sites. Based on quantitative data, they demonstrate how research output and research designs change according to the levels of contact between actual and potential collaborators. Their research outcome as well shows how scientific knowledge is co-shaped by non-scientific processes, thus surpassing the boundaries of the pure scientific.

Ulli Vilsmaier, Vera Brandner and Moritz Engbers in their chapter "*Research In-between: The Constitutive Role of Cultural Differences in Transdisciplinarity*", draw on a broad concept of research acknowledging the complementarity of academic research practices and other ways of knowing. More in particular, they focus on cultural differences and argue that acknowledging and exploring those differences represents a major potential for transdisciplinary research. They propose the creation of so-called Third or In Between Spaces that are characterized not by discrete and independent entities, as disciplines, societal domains, cultures or communities, but by the entanglement and complementary of these entities. Through explicitly addressing this entanglement in researching collaboration, they conclude, conditions are created for the emergence of a critical and culturally sensitive transdisciplinarity.

These contributions disclose, each with particular arguments, examples or empirical data, how science is contextualized in personal, group and cultural processes. One consequence is that it makes the object and the subject of knowing really intertwined, while the one is intrinsically shaping the other. *Mambet Cantemir* in his chapter "*Objectives are Subjective*" builds upon this notion of the subject and the object of knowing, pointing at the limits of objective knowledge in risk management and related decision-making. Without an objective, formulated by some "subjective" entity, risk cannot exist. Risk is neither absolutely objective, nor absolutely subjective, and doesn't have a standalone existence either objectively or subjectively. Moreover, it is important to explicitly include the notion of the Levels of Reality of the Subject and of the Object, and particularly the notion of ternary Intellect (Body – Emotions / Feelings). Using this TD methodology, he concludes, offers possibilities to improve both the techniques for decision-making and the decision-making process itself.

Zoltán Baracskai and *Viktor Dörfler,* in their chapter "*An Essay Concerning Human Decisions*" observe something similar, that the praxis of decision-making has always been transdisciplinary, but that this is usually not recognized as such. It is transdisciplinary, as it involves various Levels of Reality of the Object and the Subject, as well as meta-knowledge. They offer a transdisciplinary model of decision-making, distinguishing among the model, the method and the tool. The model refers to the persons involved in the process, with their particular Levels of the Subject. The method refers to the way the complex reality is ordered, and the tool refers to the particular way a decision is sorted out of the complexity. Meta-knowledge is essential, yet is highly intuitive and cannot be communicated in straightforward (scientific) concepts. It has its own level of reality, and is best being communicated through metaphors (thus linking meta-knowledge to metaphor).

It is a small step from the intuitive to the unconscious, a key concern in the chapter of *Paulo Nuno Martins*, entitled "*The history of the Indian sacred book (Atharva-Veda) and its Contribution to the Integrative Medicine Model*". Paulo's interest is in finding a scientific base for the traditional Indian Ayurveda healing approach. The Ayurveda mind-body medicine sees the root of diseases as an imbalance of the mind, or in other words, as an imbalance between Levels of Reality of the Subject. Healing is seen as dependent on a process of self-transformation or self-awareness, by means of making the unconscious conscious so that the consciousness mind works on restoring the balance. The chapters makes a plea for a transdisciplinary study of this phenomenon along the ideas of the Levels of Reality of the Object and the Subject, in order to arrive at an explanation of its functioning in a scientific way.

Anthony Cole, in his chapter "*Towards an Indigenous Transdisciplinarity"*, finds transdisciplinarity within the knowledge production of the Māori people from New Zealand. He compares their epistemology with Nicolescu's concept of transdisciplinarity. He sees similarities in the notion of the unification of the object and subject, the 'included middle', the concept of Levels of Reality and the notion of qualitative complexity. He shows that transdisciplinarity exists in Maori culture since ancient history, as in probably many other indigenous cultures. Therefore, Anthony makes a plea for the preservation of indigenous cultures that still exist, and calls for making room for an indigenous transdisciplinarity in Western academies.

Sacha Kagan, in his chapter "*Artful Sustainability: Queer-Convivialist Life-Art and the Artistic Turn in Sustainability Research"*, finds transdisciplinarity in artful ways of investigating sustainability. He observes that complexity has become important in contemporary society and science, and particularly in sustainability science. However, he also observes an inability to be sensitive to complexity, as in accepting that no single truth and no single way of knowing, or paradigm, can prevail. He looks for a queer approach that nourishes such sensitivity, through denormalizing and de-naturalizing aesthetic experiences and thought & embodiment processes. This leads to confrontations beyond taken-for-granted definitions and meanings. He finds an answer in arts-based research that corresponds largely to the concept of transdisciplinary hermeneutics, opening up the potential to make us experience what is with what may be, and what is measured with what is felt and intuited, without gazing for consensus or congruity among them.

Anne Bationo, Francesca Cozzolino and *Hans Dieleman*, in their chapter "*The Aesthetic Experience of Time, in between the Hourglass and the Self"*, find transdisciplinary hermeneutics in aesthetic experience, vice versa. They describe an ethnographic study into the interactions of the passengers of a French railway station with a work of art, located in that station. The work of art interrogates time, and does so in interaction with the passengers. They explore conditions for the occurrence of aesthetic experiences, and identify openness to surprise, defamiliarization and singularization, being an individual disconnected from a moving mass, as being crucial. They equally look at the process of aesthetic experiences, and observe that they occur in intermediate spaces of interaction in between the Subject and the Object, the passenger and the work of art. In such spaces, cognitive, embodied and enacted knowing work together, creating a fusion between aesthetic experience and transdisciplinary hermeneutics.

Samuel Bianchini, in his chapter "*From Instrumental Research in Art to its Sharing: Producing a Commons, Respecting the Singular"*, questions the relationships between artistic practices and academic (as well as industrial) research, and between research and creation. This brings him to reflect on the notion of instrumental art, and to rethink methods of cooperation and sharing between the arts and science. Can art fulfill artistic objectives and be instrumental at the same time? Samuel explores this question using the notion of allographic arts, presenting the example of musical notation and its subsequent performance or instatiation. Subsequently he focuses on the role of the artist, and makes a plea for the rethinking of the individual artist creating unique works of art. He proposes to rethink the notion of the I and the singular, towards a notion of 'we' without denying the 'I', and about sharing, as a concept closer to co-producing than to handing-over after a work is supposedly finished. It is clear from his chapter, that becoming really transdisciplinary implies a fundamental rethinking of concepts as art, science, creation, production, and ownership.

A last group of authors make a plea for trans- and interdisciplinarity in research and education, as this clearly has a contribution to, and positive impact on, sustainable development and wellbeing. *María Concepción Martínez Rodríguez, Luis Ángel Jiménez López* and *Omar Mayorga Pérez*, in their chapter "*From Discipline to Inter-and Transdiscipline in the Environmental Academic Sector in Mexico"*, explore the advances that Mexico has made in environmental policy and research, and in inter- and transdisciplinarity in particular. They observe that in the environmental sector, the societal and especially the industrial demands for interdisciplinary professionals are growing. These demands are largely induced by foreign capital in Mexico. However, Mexico's educational policies, and research practices, have distanced themselves too much from promoting interdisciplinarity. The authors observe that, due to this situation, Mexico will loose resources and opportunities. They make a plea for a rapid increase in inter- and transdisciplinarity in research and education, as these are key factors in promoting a sustainable development in Mexico.

Christopher Kreger, Daniel Moran and *Stacie Therson*, in their chapter "*A Transdisciplinary Approach to Unemployment In the United States' Petroleum Industry"*, explore the potential beneficial effect that education in transdisciplinarity can have on (un)-employment in the US petroleum industry. The transdisciplinary approach, they argue, allows for the mapping of the transdisciplinary framework onto problems with effects found in both civil and academic areas, with specificity in the domain, where those areas transcend their boundaries and intermingle. When transdisciplinary tools are utilized in this manner, the benefits of having both academically collaborative research, as well as industry specific expertise allow the synthesis of the potential solution set to occur more rapidly, with more robust solutions. They conclude that investments in research and development of new technologies combined with efforts to increase the education level and skilled labor pool of employees within the United States will positively impact unemployment rates within the Petroleum Industry.

Finally, *Jerome Moore* and *Adam Hines*, in their chapter "*Biomimetic Engineer-*

ing Analysis of Heliotropic Plants", explore biomimetics is the field of study that identifies potential useful biological processes and mechanisms in nature and translates these principles into the engineering domain. The chapter first introduces an analysis of plants' ability to maintain optimal sunlight in order to maximize the photosynthesis process, and continues discussing components and factors that enable heliotropism, as well as the governing physics describing the processes needed in order for this phenomenon to occur in nature. In doing so, the chapters shows how the transfer of knowledge from one discipline and field of knowledge to another, has proven to be a powerful and useful mechanism for innovation, and has led to profound technical advancements and capabilities in applied science disciplines and fields.

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CHAPTER 1

The Structure of Distributed Scientific Research Teams Affects Collaboration and Research Output

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To understand how the nature of scientific collaboration between individuals and sites in team-based research initiatives affect collaboration and research output, we examined four waves of prospective survey data to measure collaboration across investigators, disciplines, and sites to measure structural determinants of research success. 116 investigators in the five sites of the NIH-funded U54 Transdisciplinary Research on Energetics and Cancer (TREC) initiative were surveyed about their research ties with a 2011 baseline measure and followed by three additional iterations and augmented by bibliometric data. Social network analysis describes the changing structure of contact and cooperation. We found that the network structure of a team science project affects the nature and rate of publications, implying that funded projects vary in research output based on how investigators interact with each other and that the design of scientific research projects affects research output by determining levels of contact between actual and potential collaborators.

Keywords*:* Cancer; research; transdisciplinarity; team science; network models.

1.1 Introduction

Current approaches to biomedical research rely increasingly on cross-disciplinary collaboration. In addition, recent funding announcements emphasize team science and call for the development of multi-institutional collaborations or hubs that promote team science. Yet despite this emphasis, questions remain about whether the benefits of a team science based approach to research outweigh the operational and transactional costs.

Beginning in the late 1990s, the National Cancer Institute (NCI) incentivized team science through three multi-site initiatives, Transdisciplinary Tobacco Use Research Centers (TTURC), Centers for Population Health and Health Disparities (CPHHD), and Transdisciplinary Research in Energetics and Cancer (TREC).

In the present paper, we perform a social network analysis of four waves of internal survey data from TREC investigators augmented by bibliometric data to determine the extent to which collaboration across investigators, disciplines, and sites affects the timing, rate, and type of publications. This approach is unique as the first longitudinal examination of an NIH transdisciplinary initiative and as the first study allowing comparison between investigators' subjective views of collaboration and objective counts and types of shared publication. Our research question is whether active efforts by a funded research initiative to foster investigator ties (network "edges") within and across sites will affect the density, centrality, and homophily of those ties at the level of the initiative, in turn speeding the onset of publication and the diversity of disciplines and institutions represented in the authorship of those publications. Our comparison is with available data from two other transdisciplinary sites funded by NIH.

NIH Transdisciplinary Initiatives and their Evaluation

In 1999, the NIH established the first of three multi-site transdisciplinary research initiatives, the Transdisciplinary Tobacco Research Use Centers (TTURC) [1]. The Centers for Population Health and Health Disparities (CPHHD) [2] followed in 2003, and the Transdisciplinary Research on Energetics and Cancer (TREC) Initiative (http://grants.nih.gov/grants/guide/rfa-files/RFA-CA-10-006.html) was funded in 2005. TTURC was the first to undergo evaluation of its impact on research output, as measured by the timing of publications. A retrospectively-conducted bibliographic evaluation of TTURC in comparison with R01s found that after an initial two to three-year lag period, TTURC had higher overall publication rates over a 10-year comparison period [3]. In a companion article to the bibliographic evaluation, Rimer and Abrams cautioned that the ultimate impact and value-added nature of transdisciplinary frameworks may be decades away due to the time that it takes to establish effective team functioning [4].

CPHHD, the second NIH transdisciplinary initiative to be funded, focuses on the determinants of health disparities and translation of this knowledge into solutions. CPHHD is unique among NIH's transdisciplinary initiatives in its focus on local communities with high rates of disparities and its mandate to partner with these communities at all stages of the research process. Okamoto conducted an analysis of one wave of survey data from the ten-year initiative in 2015 [5] and found a similar lag period as seen in TTURC.

The TREC Initiative (2010-2015)

In 2005, TREC was funded by NCI as NIH's third transdisciplinary initiative, in response to increasing evidence of the contributions of nutrition, energetics, and physical activity to cancer incidence, morbidity, and mortality. The NCI Request for Applications (RFA) (http://grants.nih.gov/grants/rfa-files/RFA-CA-10-006.html) describes the TREC initiative's purpose as "to foster collaboration across multiple disciplines and encompasses projects that cover the biology, genomics, and genetics of energy balance to behavioral, socio-cultural, and environmental influences on nutrition, physical activity, weight, energetics, and cancer risk."(p. 1).

The TREC Coordination Center and Dr. Gehlert began prospectively gathering data to evaluate the transdisciplinary efforts of the TREC at the beginning of its second cycle of funding, in 2011. These data were supplemented data with an analysis of prospectively-obtained bibliometric data.

The TREC sites (the University of Pennsylvania, Washington University in St. Louis, the University of California-San Diego, Harvard University, and the Coordination Center at Fred Hutchinson Cancer Research Center in Seattle) comprise more than 120 investigators and over 30 clinical, biological, behavioral, and social science disciplines, with inevitable fluctuation over time due to investigator moves. Their scope extends from the biology, genetics, and genomics of energy balance to social and behavioral influences on physical activity and nutrition, weight, energetics, and cancer risk [6]. In part because of the emphasis on the specialized technology inherent in research on energetics and a reliance on animal models, systematic efforts were made to maximize resources by fostering ties across sites. This was incentivized by developmental awards requiring participation by junior and senior investigators across sites that were managed by the TREC Coordination Center. TREC was the only one of the three NIH transdisciplinary initiatives to have a Coordination Center as part of its structure.

The TREC initiative aims to accelerate scientific discovery through a *transdisciplinary* approach to team science, which Rosenfield defines as exchanging information, altering discipline-specific approaches, sharing resources, and integrating disciplines to achieve a common scientific goal [7]. 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. It is generally considered to represent the highest degree of disciplinary collaboration [8].

In a 2008 article introducing the TREC initiative in a special issue of the Journal of Preventive Medicine, Robert Croyle, who heads NCI's Division of Cancer Control and Population Sciences, wrote that "one important assumption underlying these efforts was that the speed of scientific progress and its effective application to public health problems would depend on the integration of discipline-specific efforts and increased support for collaboration, evidence synthesis, and the science of dissemination" [9]. Thus, integration among collaborators is seen as a measure of the success of transdisciplinary team science initiatives like TREC. In another article on team science in that same year, Karen Emmons (now VP, Director of the Kaiser Foundation Research Institute) was quoted as saying "*among* the most important indicators of success is rich team communication" [10].

1.2 Methods

Study Sample

Survey participants were investigators involved in the five TREC sites from 2010 to 2015. A list of investigators was developed by the TREC Steering Committee and after receiving appropriate IRB approvals, each was sent a letter inviting them to participate along with a copy of the social network survey. The 2011 survey established a baseline measure of ties after the first year of funding. The survey was re-sent yearly to assess the degree to which the density of social network ties changed over time during the height of the grant activity. Because it was sent late in 2011, the next survey was received early in 2013, 13 months after the previous year's survey. Thus, no data are available for 2012, and the time between waves was 13 months rather than 12 months. In 2013, we limit the invitations only to those who responded in 2011 and remained active in TREC. Fewer invitations were sent in 2014 and 2015 due to turnover of faculty over time, which is a typical phenomenon in such projects. The TREC Coordinating Center collected publication data on a regular basis and examined authorship in terms of the disciplines and sites represented. In the current paper, we report on data from the first four waves of data collection. The response rate of the survey is approximately 80 percent in each year, although the absolute number of respondents decreased slightly over the period of study. The number of respondents by academic position and site are summarized in Table 1.1.

Measures

Collaboration Network. The survey listed the names of all TREC investigators and asked individual respondents if they currently worked with or had worked with prior to TREC each investigator on the list: (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. These are the conditions for interacting and thus forming an edge (tie) in the researcher network. Thus, the *behavior* that we study here is two researchers deciding to collaborate in one of these six ways. Note that we are not measuring the quality of these ties, nor the resulting groups from collections of ties, except that a grant award or publication is clearly an indication of edge effectiveness.

Discipline. From a list of 37 academic disciplines, investigators were asked to choose the one that best characterized the disciplinary perspective of their work. For purposes of analysis, responses were collapsed into eight disciplines (Table 1.2). The subgroups of disciplines and the distribution of disciplines by site are described in Table 1.3.

Social Network. We consider a social network to be a relational structure among actors. We define individual TREC investigators who participated in our survey to be a set of actors (also called nodes), and assign a tie (as in "tie-together") if there are collaborations between those investigators. These ties between two actors are called arcs or edges. 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 structure to be analyzed in its entirety as well as the dyadic relationships between its members. The underlying assumption is that more frequent communication within and across sites will better foster advances in science, specifically in this case energy balance and cancer. For the purposes of analysis, we define communication as the quality of dyadic and group interactions beyond what is measured in six survey criteria for an edge. We also specify an undirected network, so that if actor 1 is tied to actor 2, the reverse is also true, because we consider peer-level scientific collaborations to be overwhelmingly mutual rather than hierarchical in this context.

Network Size. The network size is the number of actors in the network (i.e., the total number of members in the network).

Network Density. More ties between investigators imply greater network interaction, as defined above. 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 (equal to $(n^2 - n)/2$ for n individuals in an undirected network). Denser networks suggest faster propagation of information and greater group cohesion [11]. Also, individuals who conduct more information tend to be more active in terms of research goals and objectives [12].

Triads. Triangle relationships occur when two individuals with a tie have a tie with the same third individual, and the number of triangles can be greater than the number of direct ties [13], especially in network with multiple attributes and diverse individual backgrounds like TREC. Four types of triadic relations occur in undirected networks: no ties (three actors are isolated without ties/edges), a single tie between two actors while the third actor is isolated, two ties among three actors, or all three ties forming a triangle. Counting the number of these types across all possible triples, a so-called triad census [14], allows us to better understand the local social structure [15], which may not be captured by global measures or dyad density. Relative prevalence of these triangles implies that interpersonal choices tend to be mutual and transitive [15].

Centrality. Another traditional way to evaluate a network is through the node centrality [16]. While the density of a network is a global measure to understand the overall network function, centrality evaluates the power and influence of each node on social relations. For example, some actors in a network are highly central while others are not widely connected. Large differences in centrality for a given network tend to produce hierarchical structures with isolated individual actors at the periphery: a core-periphery structure [17]. We first measure *degree centrality*, which shows how many actors are tied directly to each actor. The measure is computed by counting the number of adjacencies for an actor in a network of size n, that is,

$$degree(i) = \Sigma_{j=1}^{n} I_{ij} \tag{1.1}$$

where I_{ij} is 1 if the actor i and j are connected, 0 otherwise. Our second measure of centrality is *closeness*. This measure provides an index of independence or efficiency [16], meaning the speed with which an actor reaches other actors in the network. The computation of closeness is based on summing the shortest paths (called *geodesics*) from an actor to all other actors in the network, that is,

$$closeness(i) = \Sigma_{j=1}^{n} (1/d_{ij})(n-1) \tag{1.2}$$

where d_{ij} is the geodesic distance between i and j. This closeness score is rescaled between 0 and 1. It is 0 if an actor is an isolate, and 1 if an actor is directly connected to all others.

We also measure centrality by the location of actors of high academic rank (full professors), which can be seen as a measure of the effect of *seniority*. Our third centrality measure is *betweenness*, which quantifies the number of times of an actor being situated as a bridge along the shortest path between two other actors, to assess how likely this actor is to be a direct route between two actors that are not linked otherwise. This measure is computed by

$$Betweenness(k) = \Sigma\Sigma_{i<j}^{n} g_{ij}(k)/g_{ij} \tag{1.3}$$

where $g - ij$ is the number of the shortest paths linking$i$ and j, and $g_{ij}(k)$ is the number of the shortest paths linking i and j that contain k.

Homophily. Similar actors tend to bond with each other for many reasons such as opportunity, affinity, ease of communication, reduced transaction costs, and organizational foci [18-21]. We assume that a tendency toward homophily that exists in the TREC network consists of eight subgroups by discipline and five subgroups by site, within which network members are easily accessible to each other. An effective way to view homophily is through the exponential-family random graph model (ERGM) [22, 23]. The model suggests the probability to be connected between i and j individuals in the network. A tendency toward homophily indicates a higher probability of ties being formed between actors within the same site or within the same discipline.

Number of Publications and Authorship. As per the initial NCI Request for Proposals (http://grants.nih.gov/grants/rfa-files/RFA-CA-10-006.html), we consider the establishment of collaborations among disciplines (i.e., biology, genomics, and genetics of energy balance and behavioral, socio-cultural, and environmental factors that determine cancer risk) as a key measure of TREC's success. In addition to measuring these collaborations subjectively, we measured collaborations within and between TREC sites in terms of the authorship of those papers across disciplines and sites. Examining the production of papers across time allowed us to investigate whether the lag time seen in TTURC and CPHHD was also true of TREC.

Although others have measured impact of publications using citation counts [24], we did not consider the four years of our study sufficient time for citations to accrue in a way that would reflect impact. We thus considered citation data to be a less reliable measure of research output. It will be the subject of future papers as the opportunity for TREC work to be cited increases over time. Data were collected from the Coordination Center at Fred Hutchinson Cancer Research Center through the Annual Progress Report to the National Cancer Institute and the citations of the TREC Center grant number in PubMed. We explored the authorship of each paper reported retrospectively in terms of the disciplines and sites involved.

1.3 Statistical Analysis

Social network analysis was used as the principal mode of analysis in the present study. All statistical results and graphs were analyzed using R version 3.0.3 [25], and the *network, sna,* and *ergm* R packages [26-28] were specifically used.

1.4 Results

The network properties of the TREC research sites over years are summarized in Table 1.2 Note that the network size shown in Table 1.2 is different from the number of respondents for the survey reported in Table 1.1. The difference between the number of respondents and the total number of network actors is due to the secondary actors who are included in the network because, although they did not themselves respond to the survey, they were designated by respondents as a link. Thus, we do not know about the relationship among the secondary actors. We take this into account in our analyses 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 sets of respondents each time point.

The density of TREC network is 0.086 in 2011 and remains similar or slightly decreases over time (Table 1.2). The relatively lower density 0.082 in 2015 does not necessarily mean less collaboration, because we observe more ties in 2015 than in 2011 (547 vs. 415). The lower density means that there are fewer social ties among actors relative to the chances of those ties occurring, which can occur simply because a network is large. As seen in Table 1.1, the network size was noticeably smaller in the first year of the grant (n=99), when researchers were building new relationships, than in subsequent years when it stabilized in terms of total participants (n=116, 114, 116). Network ties expanded rapidly in the early period, going from 414 in 2011 to 577 in 2013. However, network ties then stabilized in the mid-500s (t=577, 525, 547). Note that these are not equilibrium values in the traditional long-run sense since the study contains only four waves.

Triad census is reported in Table 1.2. Triangle relationships increased over time, from 592 in 2011 to 1175 in 2015. These numbers are translated to the *Transitivity Index 1*, by dividing by all possible triads, and *Transitivity Index 2*, by dividing by the number of one-tie triads. Both transitivity indexes increased in 2015. The second index implies that the characteristics of the small group relationships have been changing from "couple only" to "triangle" in general.

Transitivity of interpersonal choices forms a more clustered structure, as evident in Figure 1.4. In a transitivity network, the existence of the two ties, a↔b and b↔c, will increase the probability of another tie a↔c, which represents the closure of the triangle. Transitivity therefore leads to the larger connected groups by particular clustering members [14, 15], which are a small number of highly active members surrounded many much less active members creating more triangles than a network with ties distributed uniformly randomly.

The density by each site is displayed in Table 1.2. A decreasing trend in density is most noticeable in Sites 1 and 2. This occurs because of the lower number of survey respondents in later years and because the total TREC social network has built up more cross-site relationships over time as researchers from different institutions collaborated more closely.

In Table 1.2, we report the mean and standard deviation (sd) of three types of centrality measures. In terms of *degree centrality*, we see an average of eight to nine edges for an actor per year, as shown in the measure of the degree 8.38, 9.95, 9.21, 9.43 in each year. In terms of *seniority,* we find that the degree of the group of investigators of high academic rank is greater than the network average for all members. We likewise see that it increased over the period of the study, which indicates that senior faculty play a central role as coordinators or gatekeepers amongst the total investigators [29]. As can be seen in Table 1.2, the scores do not differ markedly among actors, as indicated by low standard deviations in all years. Each member thus has a similar level of dependency (or efficiency) to connect to every network member. In Table 1.2, we see a large standard deviation of the *betweenness* among actors. This indicates that a small set of actors perform key brokerage functions within the network [29]. Individual differences can be seen in Figures. 1.1-1.4, where the size of the node indicates the degree of the ties for each investigator. Although this refers to the degree, it indirectly shows the betweenness distribution among the actors, since these two centrality measures are highly correlated.

In Figure 1.1, each node indicates an individual investigator, and is colored according to discipline, with sites labeled by the letters A to E. We see that the network is clustered by site, and there are key players in each site with large sized circles for greater relative connectedness. For instance, in site A, some investigators in epidemiology and biochemistry/genetics are shown to be key actors in the local network. However, a member in exercise and physiology, located in the center of site B, is similarly highly connected. In site C, the epidemiology and social behavior science fields are at the center of the diagrams. In site D and E, each actor shows widely spread, but more diffuse connectedness in the local network. Therefore, some disciplines are more influential in some sites than others. Combined, these observations imply the collaborations *across* the sites implies cross-disciplinary interactions between geographically distinct leaders.

Homophily. From Table 1.2, the lines of the homophily, we report the results from two separate ERGM models across both site and discipline. Not surprisingly, there is a homophily effect by both site and discipline over four years, as shown by a small p-value (<0.01), meaning that actors are more likely to make ties with those in their own site than those in other sites. A similar interpretation is possible for disciplines. Also, the probability of collaboration within site was 0.311 in 2011, which is higher than the overall density 0.086: the density can be interpreted as the probability of ties of two actors in general. However, we notice that the probability of ties within sites monotonically decreases over time to 0.219 in 2015. Within-site homophily tendency decreases as cross-site collaborations increase. Likewise, the probability of collaboration with someone from the same discipline was 0.145 in 2011, which is higher than overall density 0.086, after which the number decreases over time. The homophily by discipline is relatively less strong than homophily by site, suggesting that the "transdisciplinary" team mission has been well performed since the beginning of the TREC.

Number of publications. Publication numbers by year are summarized in Figure 1.5. The number of publications increased in later years of TREC as we expected from the expanding collaborations in TREC centers. Furthermore, we calculated the number of papers in which the coauthors were from multiple disciplines and from multiple sites. These numbers are also reported in Figure 1.5. Note that information about discipline of authors of papers was not universally accessible. We therefore used information collected in our longitudinal survey and our central TREC directory of TREC investigators, for which only 40% of disciplines are known. This may have resulted in an underestimate of the number of disciplines per publication. In counting multi-site publications, we included both TREC sites and non-TREC sites because the coauthors from non-TREC sites indicate extended collaborations with TREC and spinoff from TREC projects. Having either multi-site or multi-disciplinary authors on a publication is common across all years.

Nature of Collaboration

Perhaps most striking is the rapid development of cross-site ties. In Table 1.4, we reported the proportion of cross-site versus within-site ties. In 2011, the cross-site ties only account for 15.66% of total ties, increasing over time to 39.67% in 2015. This phenomenon is shown graphically through Figures 1.1-1.4. The network in Figure 1.1 is clustered by site, whereas the network in Figure 1.4 exhibits a well-mixed cluster of sites. This occurs because cross-site collaborations increased over the years. The number of cross-site ties after the first year was twice as high for TREC than for CPHHD [5], the only other NCI-funded initiative for which they were measured, during the first year of its second round of funding, the only year in which CPHHD network ties were measured. In terms of type of collaboration, we see that in 2011, grant and committee collaborations were most prevalent, while co-authored publications were most prevalent from 2013 to 2015.

1.5 Discussion

Several things are notable in terms of the collaborations among TREC investigators over time and the research output that accrued. In terms of subjective reports of collaborations, we see that the number of network ties increased over time. These network ties are reflected in an objective count of the numbers of peer-reviewed publications with authors from multiple disciplines and publications that cross sites. This suggests that TREC was successful as defined in the original NCI Request for Applications for TREC (http://grants.nih.gov/grants/rfa-files/RFA-CA-10-006.html).

Our comparison of network ties is with the one year of data collected from CPHHD. We found many more cross-site ties after the first year of TREC than were observed after the first year of CPHHD. In retrospect, we anticipate that this likely was due to the use of the TREC Coordination Center as a natural network hub for TREC, an unanticipated consequence of the use of a cross-site coordinating mechanism. Neither TTURC nor CPHHD had such a center as part of its structure. The Coordination Center fostered cross-site ties through establishing and maintaining mechanisms such active monthly steering committee teleconference calls with representatives from each site and NCI, cross-site working groups representing multiple disciplines on topics such as cancer disparities, biomarkers, and measures of physical activity, and designated cross-site developmental awards that privileged junior and senior investigators working together, mandating that more than one site be represented.

Our results show two main differences between TREC and the other two NIH transdisciplinary initiatives. In comparison to the CPHHD, which also compared within-site and cross-site network ties after its first year of functioning, TREC had many more cross-site than within-site ties. We expect that this is due to CPHHD's mandate to partner with communities, which drew investigators inward, while TREC investigators' emphasis on technology caused us to look across sites for resources to share. At the same time, the Coordination Center fostered and facilitated the sharing of resources and expertise across sites. Secondly, because TREC was able to promote and support work across disciplines and site, in part through the Coordination Center, TREC did not experience the two to three-year lag in publications to the same degree as TTURC and CPHHD [2-4].

Both our survey and the bibliometric results consistently show that TREC collaborations have been growing and emblemize successful team science in public health and medical research. Both cross-discipline and cross-site collaborations contributed to this growth. Importantly, the analysis here suggests that multi-site team science initiatives are more likely to foster greater collaboration and cooperation when they are designed to be transdisciplinary from the start, whereas one previous study [24] found that across all types of biomedical studies increasing physical distance between investigators is a major deterrent to scientific impact. In the current environment of shrinking grant support, funding agencies may want to consider focusing on transdisciplinary team science as a way to increase research success for a given level of funding.

In analyzing the network, our study has some limitations since it is a longitudinal study. Losing or adding members in a network in successive years makes some measures less comparable. Lower density can occur simply because of a different size of network or a heterogeneous set of actors of each year. Also note that the density measure is based on dyad relationships, ties between two actors, which may not capture the local social structure like a triangle. Rather than relying solely on results of density, we also looked at the nature of relationships through a triad census and the exponential random graph model. The TREC network is a good example of change in that the overall density is similar over a given year, but the nature of local relationships can change. Another issue may come from the inclusion of the secondary actors who are designated by the survey respondent but did not participate in survey. The number of secondary actors were 21 out of 99 in 2011, 40 out of 116 in 2013, 55 out of 114 in 2014 and 59 out of 116 in 2015. More secondary actors that we have more missing, and therefore the overall edges are underestimated by the survey. Fortunately, we could locate more defined groups, notably triangles, in the network with the most secondary actors [29], buffering our general conclusions.

Our analyses of TREC data are ongoing. The number, pace, and nature of publications are important and visible academic outcomes for any scientific team, as are citations of those publications. As stated earlier, while we considered it premature to analyze article citation data, we intend to do so retrospectively after publications have had time to collect citations in the normal fashion. In the meantime, our network survey data are highly nuanced and provide extensive insight into dyadic and group collaborations as well as network dynamics, improving upon previous investigations from NIH-funded projects.

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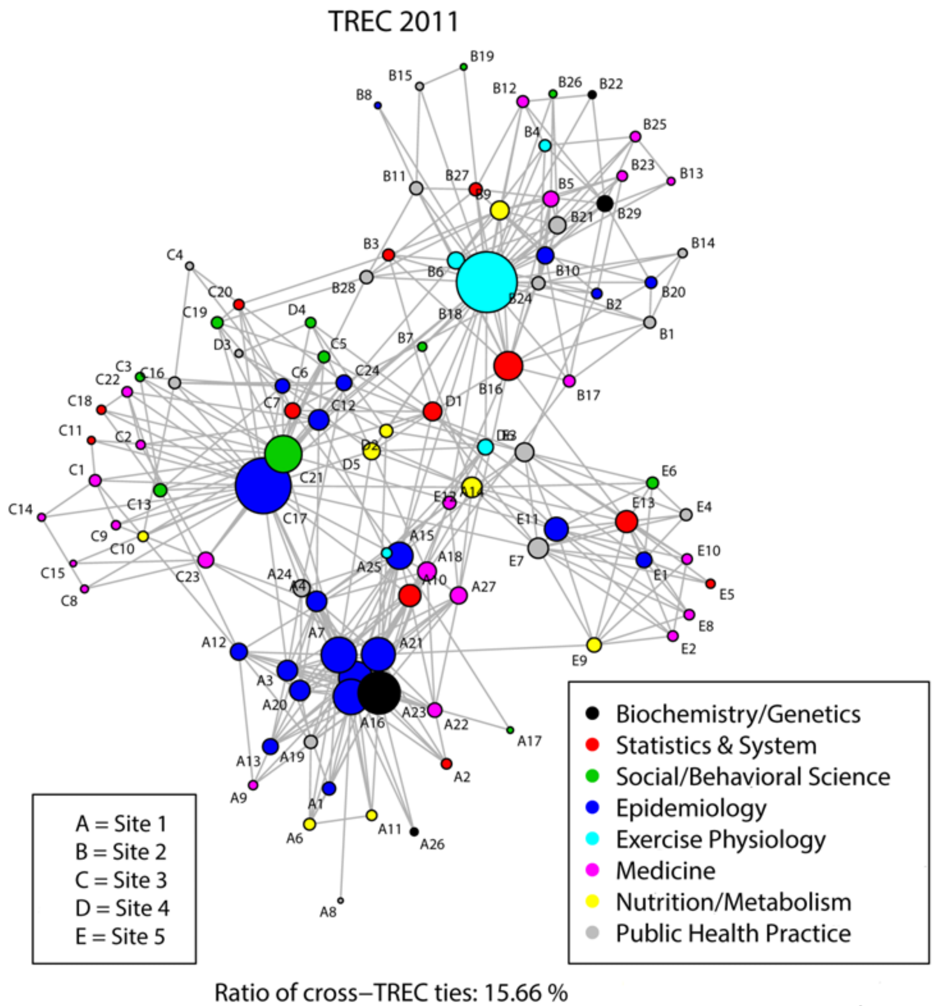

Figure 1.1: Network plot of the five TREC sites in 2011. Each node indicates individual investigator, which is colored by different disciplines and labeled by the letters A to E for different sites. The size of node indicates the degree of the ties that each investigator has. It is clearly seen that the network is clustered by site.

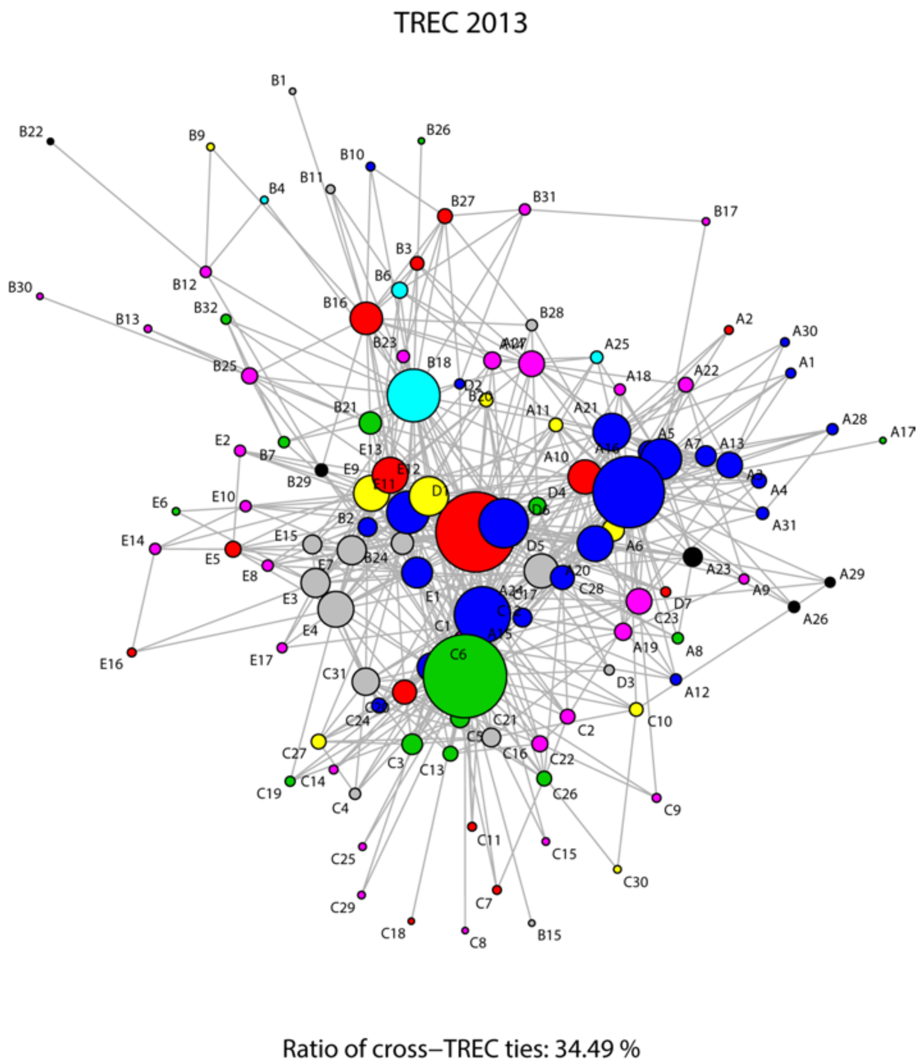

Figure 1.2: Network plot of the five TREC sites in 2013. This network exhibits a well-mixed cluster of sites compared to Figure 1.1. This occurs because cross-TREC collaborations have increased to 34.49% in 2013 from 15.66% in 2011.

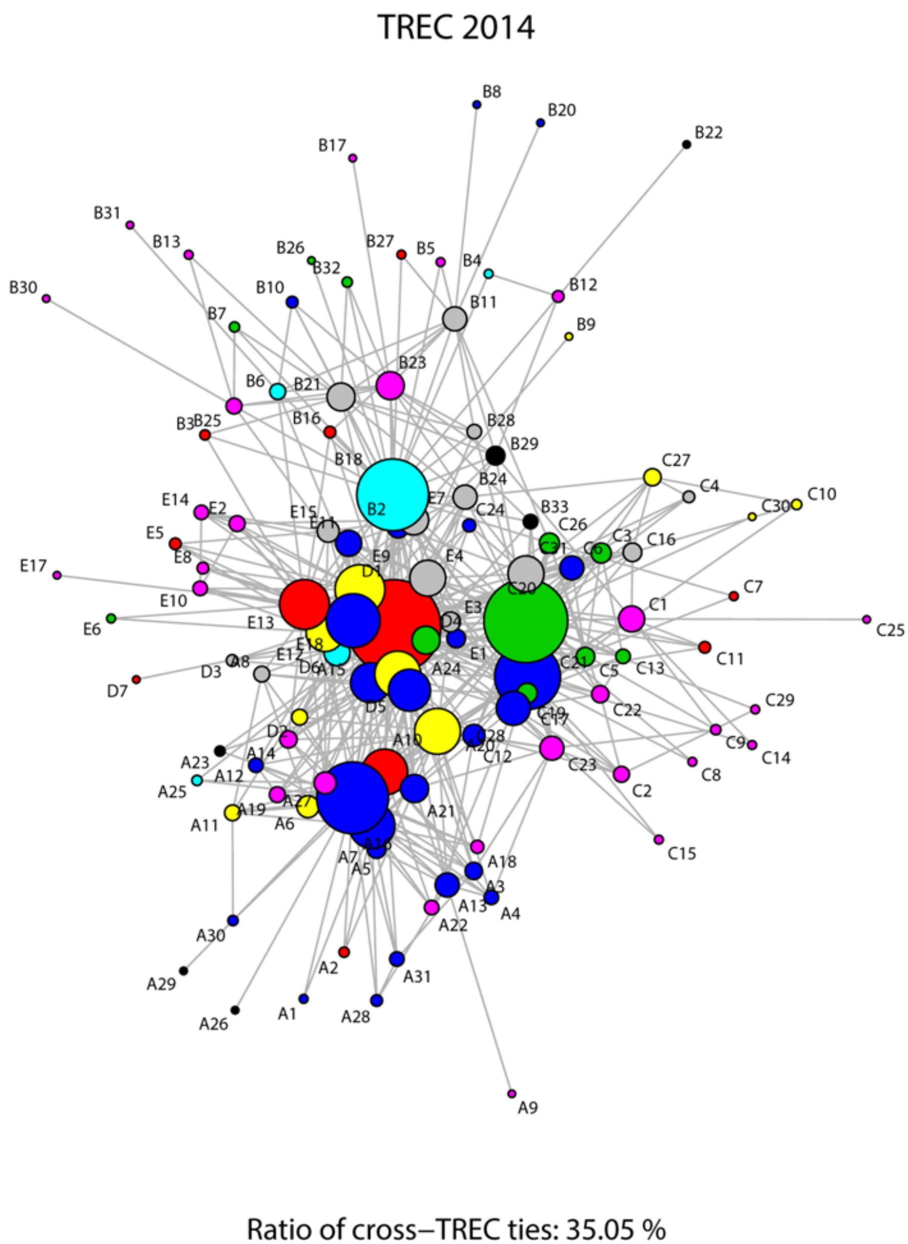

Figure 1.3: Network plot of the five TREC sites in 2014. The cross-TREC collaborations have slightly increased to 35.05% in 2014 from 34.49% in 2013.

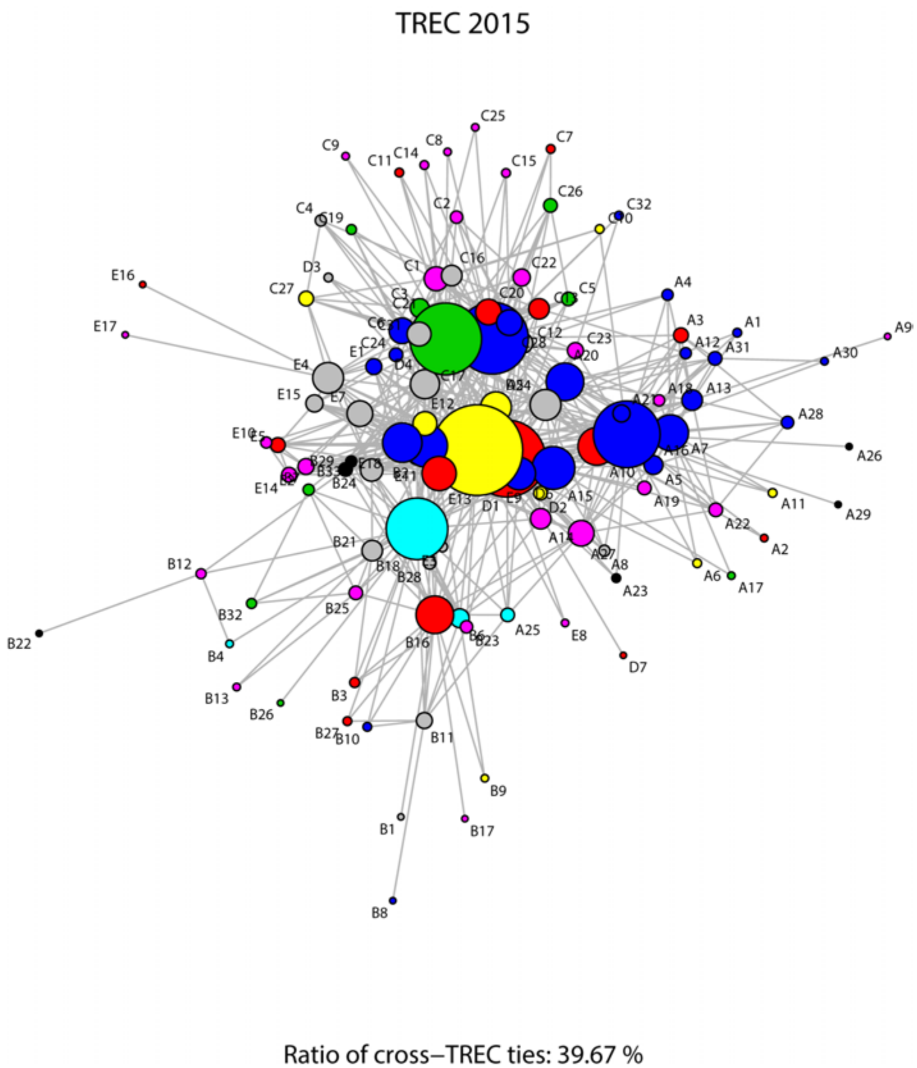

Figure 1.4: Network plot of the five TREC sites in 2015. The cross-TREC collaborations have increased to 39.67 %, from 35.05% in 2014, which is also more than two times from 15.66% in 2011.

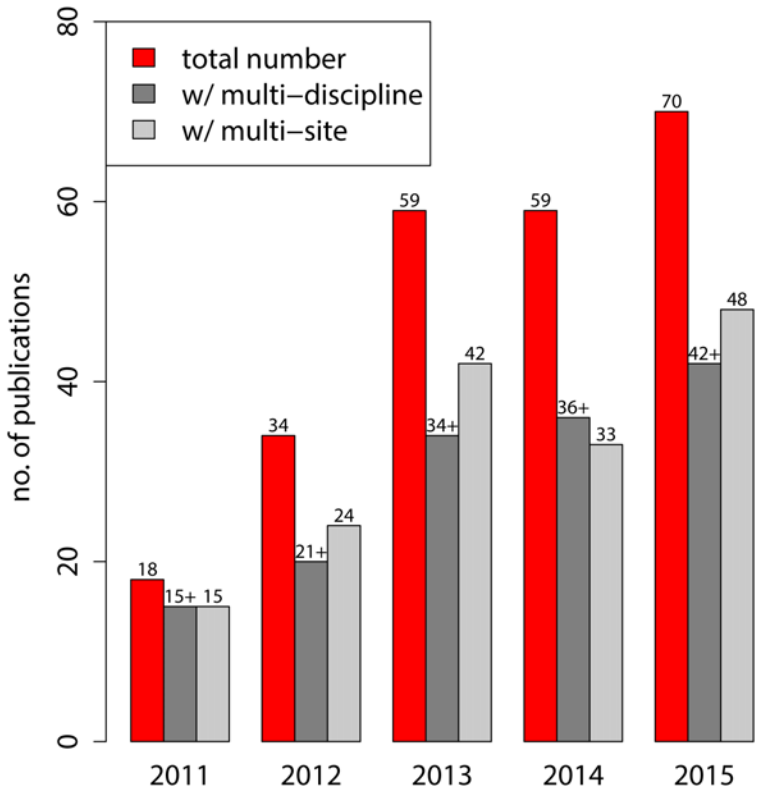

Figure 1.5: The number of TREC publications per year.

Table 1.1: Summary of TREC Social Network Survey Response for 2011-2015

		2011	2013	2014	2015
Number invited for survey		100	92	72	70
Number of respondents (rate)		78 (78%)	76 (83%)	59 (82%)	57 (81.4%)
Number of respondents by academic position					
	Professor	30	30	21	24
	Associate Professor	21	17	15	14
	Assistant Professor	12	17	10	9
	Research Associate/Fellow	8	4	4	1
	Other	7	8	9	9
Number of respondents by TREC site (No. invited)					
	Site 1	21 (27)	24 (25)	15 (15)	14 (20)
	Site 2	20 (29)	13 (22)	10 (20)	10 (15)
	Site 3	20 (25)	20 (25)	19 (22)	18 (20)
	Site 4	5 (6)	6 (6)	5 (5)	5 (5)
	Site 5	12 (13)	13 (14)	10 (10)	10 (10)

Table 1.2: Network Properties of TREC sites in 2011-2015

	2011	2013	2014	2015
Network size (N)	99	116	114	116
Network size by disciplines				
Biochemistry/Genetics	4	5	6	6
Statistics & System Science	12	14	13	16
Social/Behavioral Science	11	14	11	11
Epidemiology	21	25	26	26
Exercise Physiology	5	4	5	4
Medicine	22	29	29	27
Nutrition/Metabolism	8	10	11	9
Public Health Practice	16	15	13	17
Number of ties (collaborations)	415	577	525	547
Density	0.086	0.087	0.082	0.082
Density within each site				
Site	0.356	0.273	0.246	0.213
Site	2 0.236	0.138	0.148	0.131
Site	3 0.261	0.234	0.206	0.225
Site	4 0.733	0.762	0.667	0.619
Site	5 0.590	0.485	0.471	0.412

Table 1.2: Network Properties of TREC sites in 2011-2015 (continued)

	2011	2013	2014	2015
Triad Census				
No ties	120,893	196,698	189,688	200,402
One tie	32,249	48,851	43,695	44,933
Two ties	3,115	6,806	6,138	6,950
Triangle	592	1,105	943	1,175
Transitivity Index 1 (%)	0.38	0.44	0.39	0.46
Transitivity Index 2 (%)	1.84	2.26	2.16	2.62
Centrality of actors				
Degree (mean (sd))	8.38 (6.11)	9.95 (9.29)	9.21 (9.08)	9.43 (10.1)
Degree (Professor only)	10.69 (7.63)	17.07 (10.52)	18.10 (10.85)	19.13 (10.98)
Closeness (mean (sd))	0.68 (0.09)	0.65 (0.14)	0.65 (0.12)	0.62 (0.14)
Betweenness (mean (sd))	76.36 (189.93)	76.40 (206.86)	81.21 (208.35)	71.35 (185.47)
Correlation between Degree and Betweenness	0.835	0.830	0.835	0.878
Homophily (Probability of ties between two actors within site and discipline				
Site	0.311	0.248	0.233	0.219
(p-value)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
Discipline	0.145	0.131	0.124	0.120
(p-value)	(<0.001)	(<0.001)	(<0.001)	(<0.001)

Table 1.3: Distribution of Disciplines by Site Appeared in the Network through 2011-2015

Disciplines	Site 1	Site 2	Site 3	Site 4	Site 5	Description of disciplines
Biochemistry/Genetics	11	10	0	0	0	
2011	2	2	0	0	0	
2013	3	2	0	0	0	Biochemistry, Genetics
2014	3	3	0	0	0	
2015	3	2	0	0	0	
Statistics & System	9	12	17	7	10	
2011	2	3	4	1	2	Biostatistics, Statistics,
2013	2	3	4	2	3	Informatics, Computer
2014	2	3	4	2	2	Sciences, Systems
2015	3	3	5	2	3	Dynamics, Engineering
Social/Behavioral Science	4	14	22	3	4	Social Work, Psychology
2011	1	3	5	1	1	Communication,
2013	2	4	6	1	1	Economics, Sociology,
2014	0	3	6	1	1	Urban Planning,
2015	1	4	5	0	1	Anthropology
Epidemiology	52	15	19	2	10	
2011	11	4	4	0	2	
2013	14	3	5	1	2	Epidemiology
2014	14	4	5	0	3	
2015	13	4	5	1	3	

Table 1.3: Distribution of Disciplines by Site Appeared in the Network through 2011-2015 (continued)

Disciplines		Site 1	Site 2	Site 3	Site 4	Site 5	Description of disciplines
Exercise Physiology		4	12	0	2	0	
	2011	1	3	0	1	0	
	2013	1	3	0	0	0	Exercise Physiology
	2014	1	3	0	1	0	
	2015	1	3	0	0	0	
Medicine		23	29	37	0	18	Oncology,
							Endocrinology, Nursing,
	2011	5	6	8	0	3	OB/GYN Pathology,
	2013	6	8	10	0	5	Geriatrics, Cardiology,
	2013	6	8	10	0	5	Urology, Pediatrics,
	2015	6	7	9	0	5	Immunology
Nutrition/Metabolism		9	4	9	8	8	
	2011	2	1	1	2	2	
	2013	2	1	3	2	2	Nutrition, Metabolism
	2013	3	1	3	2	2	
	2015	2	1	2	2	2	
Public Health Practice		7	22	12	5	15	Behavioral Health, Health
	2011	3	7	2	1	3	Services, Population
	2013	1	6	3	1	4	Health, Health policy,
	2013	1	4	3	1	4	Environment Health,
	2015	2	5	4	2	4	Public Health education

Table 1.4: Nature of Collaboration for TREC sites in 2011-2015

	2011	2013	2014	2015
Proportion of cross- and within-TREC ties	15.66% vs. 84.34%	34.49% vs. 65.51%	35.05% vs. 64.95%	39.67% vs. 60.33%
Collaboration type (unit: % of the total ties in each year)				
Grant	43.38	42.77	42.00	49.08
Co-authored publication	24.67	35.29	42.94	53.69
Co-authored presentation	14.82	15.67	23.88	28.23
Mentorship	18.10	21.64	23.18	25.92
Committee	34.82	36.10	33.41	33.29
Others	7.65	7.68	7.65	8.06

CHAPTER 2

Philosophy of Transdisciplinarity: Approaches to the Definition

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The article shows that the experience of practical philosophizing is the cornerstone of the possibility to define the philosophy of transdisciplinarity. The conditions for this experience are an active and motivated participation in the solution of actual existential problems connected with the existence of objects proportional to the person. Along with traditional forms of disciplinary scientific knowledge (natural and social sciences), a wide range of daily practical knowledge, religious and other experiences are involved in the production of knowledge required for dealing with these problems. The article notes that, owing to boundary nature of transdisciplinary experience, its conditions both precede the experience as an accumulated knowledge, and at the same time are newly redefined and become others (are in a sense generated) depending on concrete circumstances of the experience. The result of such interaction is a paradoxical development of practical activities whose "aposteriority-aprioristic" forms combine a variety of universal definition of what is disciplinary and generally valid by agreement of daily, practical knowledge. Owing to the above, the philosophy of transdisciplinarity has, among other features, an incomplete, procedural nature of "open work" (U. Eko), and the style of philosophizing is developed in three main transpositions (the observer, the participant, the witness).

Keywords*:* Transdisciplinarity philosophy, practical experience, casus, reflection, transposition concept.

2.1 Introduction

We are going to use the term "transdisciplinarity" in contrast to the term "interdisciplinary" for defining such cognitive situations in which, for various reasons (which we are going to discuss below), the scientific mind (both in the science and philosophy) is compelled to search for integrity and its own validity (in order to clarify the conditions of possible experience) and make a transcending shift to *the sphere bordering on the life-world*.

Powerful impulses coming from the purely practical sphere are prerequisites for this shift. This is a need for development of a problem-oriented research aimed at finding solutions of current practical problems such as those in the field of environment, energy, information, demography, health problems, etc. As a result a new type of research activity - generating scientific knowledge is formed. In sociology and philosophy of science it is being researched under the name of “postnonclassical science" (V.S. Styopin), “type 2 science" (Gibbons M., Nowotny H.), postacademic science (Ziman, J), science of ‘another Art Nouveau’ (U. Beck), et al. The modern type of scientific knowledge generating is a hybrid of fundamental research oriented towards cognition of some true state of affairs and the research pragmatically oriented towards achieving some useful effect. For example, discovery of genes or stem cells is followed by their patenting which requires description of their useful properties. It is no coincidence that this type of scientific activities is highly commercialized. Its execution is carried out in a complex network of academic, commercial, government, and non-government public institutions. In the classical type of knowledge generation the value system exists in a somewhat implicit way (like Merton ethos of science) and is controlled by the system of intrascientific mechanisms. In the new type (which is expressed mostly in biology and medicine) a reflection arises for this system of values which is implemented through these very transdisciplinary mechanisms of normative registration of scientific practices (institutionalized both within and beyond science). In these transdisciplinary mechanisms representatives of humanitarian disciplines (especially, philosophers) and public members are playing an active role. It is important to emphasize that transdisciplinarity has proven to be one of the vectors of the multidimensional transgression of modern science beyond its classical identity. Precisely in this respect it shows up as a matter of philosophical discussion.

However, science does not cease to be science and philosophy is not changed into ‘philodoxy’ (I. Kant). Philosophy’s advancement to the limits of the life-world turns out to be a result of search of its own *grounding*, realization of the need in *justification* and *consistency* of its own judgments. The science moving in the same direction gets a chance to preserve the integrity of world perception which it inevitably loses in the increasing disciplinary fragmentation. At this, philosophy and science entry a special *border regime* of its existence, adapting to the *experience of the* limit [1]. From our point of view learning the transdisciplinary experience makes it possible to reveal a positive sense of the crisis phenomenon of the scientific mind self-identity (of science and of philosophy as the science of sciences). This crisis frightened and continues to frighten some researchers with potential negative consequences endangering modern culture in general. It caught and continues to catch magnetic interest of others.

At the same time it has a positive value in terms of defining the individual features of each knowledge type as a result of meeting with other. Meetings of science and philosophy which happened many times at the breaking moments of their historical development are examples of it. For us the pivotal fact is that the next meeting of the disciplinary scientific knowledge with philosophy and of philosophy with scientific knowledge is actually happening here and now on the borders with the life-world, defining the specifics of the phenomenon which we call transdisciplinarity. In order to characterize the specificity of this “here and now" we have used another term that needs to be clarified - the term of “bioethics" casus.

We borrow the term “casus" from the civil law tradition (the most typical example is the United States) where precedents (casus or cases) play the regulatory role. The court decisions on private legal conflicts act as standards for evaluation and decision-making in other situations [2]. *The single thereby turns to be a source of the common.* In this sense, the "casus" is fundamentally different from the "example" indicating application of a general rule to a particular case or granting empirical concepts reality in contemplation (I. Kant).

In the context of our application the casus can be defined as a specific case or a life *episode* which provokes a variety of disciplinary and extradisciplinary responses (responsibility) and at the same time ties them into some joint effect acting as some common *reason* (leash). Next, and this is already assumed in the above, the casus provides some space of *opportunities* for these answers, their "possibility" (V.S. Bibler), or "virtuality" (G. Deleuze), yet again, not in the form of intelligible basis, but as a real event in the life-world of the man. Moreover, the sphere of possibilities includes specific circumstances of the case, and its *position* (place) in the social-cultural context. Therefore, generally the casus shall be understood as a ground-breaking *event* provoking search for specific grounds, justification, and consistency of philosophical and scientific discourses in transdisciplinary practices.

Of course, not every incident can become a casus. It is essential that the life incident has a *momentum provoking a need for comprehension*, for advancing beyond the limits of the ordinary, popular belief ("doxa"). A life incident must be *paradoxical.* It must contain a mandatory requirement for scientific, philosophical, theological and other disciplinary understanding, i.e., nomination beyond the life-world in search of a theoretically grounded idea of truth or benefit which could aspire to the status of universal. If we try to schematize it, we can say that the universality embodies integrity of sense and drawing the subject into itself as a problem of identifying the connection of the single with something radically other [3]. For this to happen the casus should have the quality of tragic 'aporia' or 'amechania': "This is impossibility to act in conditions of necessity to act. It originates not from a consciousness of the world's "upset", yet, in clear opposition and confrontation of equally powerful and equally right forces or needs ..." "Plunging into this aporia, the energy ... of actions is converted into the energy of thought, or rather, into the energy of consciousness" [4].

Existential energy of the life incident aporia is executed in the variety of scientifically, philosophically, theologically and disciplinarily justified decisions. Yet, the complexity of existential problems (bioethics, ecology, or energy) is that no disciplinary justifications at any *necessity* can claim to be *sufficient.* Truth faces truth, goodness faces goodness, veritas faces veritas causing *aporia of mind* and generating a paradoxical impetus for seeking the grounds and consistency, yet now in the sphere of transdisciplinary communications of the life-world - in the sphere of universal significance. The universal significance expresses a social convention and is based on the object composition of a joint action of a group.

It is only the presence of this double, oppositely directed, localized on the boundaries of disciplinary and life-worlds impetus of paradoxality that turns an incident into a transdisciplinarity casus. Thus, the phenomenon of disciplinarity clearly demonstrates the dual nature of our idea of universality and fundamentality of the life-world in which the diversity of human activities unfold. The universe and the integrity of the human presence in the world are based on the mobility of the "tectonic plates" of universality and general validity, which form it unitedly and distinctly.

Once again we emphasize that the variety of casus in bioethics, which concern both the scientific community and public opinion, makes bioethics itself a casus in the above mentioned sense. It is in this sense that we consider the casus of "bioethics", i.e. as a kind of a specific event being an impetus for the emergence of philosophy of transdisciplinarity, and not just as a form of application of "fundamental" philosophical (anthropological, ethical, etc.), biological, medical, and other disciplinary knowledge to specific situations in the biomedical science and practice. The traditional 'paternalistic' opposition of fundamental and applied knowledge is counterproductive in this case.

Initially bioethics was formed as a transdisciplinary approach to understanding and finding answers to complex moral and anthropological problems arising from the development of biomedical technologies (sometimes literally - on the verge of life and death). At the same time from the very beginning a fundamentally important pre-understanding (yet, not based on any theoretical concepts) has practically developed, according to which:

1. The question of what is the benefit of patient, or the good of society in situations generated by advances in biomedical technologies, can not be solved exclusively based on an expert opinion of natural scientists. The interdisciplinary cooperation with representatives of the humanities (especially philosophy) is vitally important.
2. There is no single moral theory or religious doctrine, which could offer a system of universally recognized values or anthropological ideas to address the rapidly increasing number of moral conflicts and difficulties.
3. Responsible decision-making on the verge of death requires transdisciplinary cooperation of medical doctors, biologists, philosophers, and other public experts on the one hand, and representatives of the public on the other.
4. The trend is that a public forum becomes an area of final decision-making. At the same time bioethics itself (through the feedback mechanisms) becomes a factor of public space formation.

Cloning, organ transplants, euthanasia, gene therapy, and eugenics - these and many other "incidents" (events) in the history of biomedical science of recent years due to their inherently paradoxical nature provoked and continue to provoke work of philosophers, physicians, biologists, lawyers, theologians and other experts, urging them to look for answers to the most pressing ethical and anthropological problems. These problems are the reason that pulls together efforts of experts and representatives of the public into a joint action and in this sense this is a *foundation* of their unity regardless of all the differences in their basic disciplinary positions.

Thereby *grounded* (and this means rational) decisions are made in an equivocal or bijudicious way (S.S. Neretina). Firstly, they are made in the context of the diversity of expert opinions (disciplinary justification in categories of the universal). Secondly, – in the context of a complex multi-level transdisciplinary dialogue as a general validity achieved by agreement. Thus, transdisciplinary communicative practices of bioethics at the borders with the life-world (in the border environment) form *a new type of justification* (rationality) of human actions in acute existential situations, which in the long run provokes exit into the borderlands.

For the bioethics casus the following statement of J. Habermas is quite truthful: "Ordinary life turns out to be the most promising medium capable to restore the lost unity of mind which earlier the expert cultures or yesterday's classical philosophy of mind claimed" [5].

Yet, restoring unity and consistency through communication practices of ordinary life, the scientific mind (both in the form of philosophy and the form of science) appears in the most serious crisis of the self-identity (self-identification). After all, it claimed to have a privileged access to the world in terms of truth (knowledge and power), exposing the prejudices of the ignorant representatives of the world in terms of opinions of the common people. And suddenly there is a situation in which achievement of integrity and *justification, rationality* of making a vitally important solution requires a kind of simplification.

The casus of “bioethics" is the source for setting basic philosophical problems - *how can the paradoxical experience of transdisciplinarity exist? How can intelligent communication without generalization within a particular disciplinary perspective be possible? What are its a priori conditions*? At the same time from the very beginning we already have the first of the conditions as an incident provoking thought, i.e. the case of “bioethics" itself. It is given here and now as a special kind of experience forcing philosophy to make a new step in rethinking of its grounds. This is a vital and practical condition for possibility of experience of the transdisciplinarity philosophy.

The philosophy of transdisciplinarity continues the tradition of philosophical knowledge to raise total theoretical and practical claims. Yet, by maintaining a thematic relation to the whole as its primary intention, it searches for the whole in counter streams, in the media of transdisciplinary communication on private and individual incidents of problem-oriented research tasks - casus. Interpreting a casus the philosophy of transdisciplinarity (following its generalizing intention) inherently comes beyond the limits of its singleness, suggesting some or other universal. The philosophical thinking can not happen without this component. However, on the other hand, every casus has an ability of generating not only one philosophical interpretation, but a whole range of possibilistic universal interpretations, each of which is special. Moreover, the base (unity) of this *special general is just a single* incident that constitutes their contextual definition here and now.

Therefore, the aim of our study is to clarify the *conditions of the possibility of transdisciplinary experience*, which appear to be paradoxical establishments , of the conditions for “a posteriori a priori" generating the philosophy of transdisciplinarity.

Given the limited volume of the article, let us consider the conditions of the possibility of transdisciplinary experience only in two aspects - from the point of view of the character of the existential mood and its most important theming.

2.2 Transdisciplinarity: Unity by Mood

The experience of transdisciplinarity is immanent to the most radical understanding of the essence of philosophy. In this regard we shall recall the authoritative judgment of Merleau-Ponty that “It means also that philosophy itself must not take itself for granted, in so far as it may have managed to say something true; that it is an ever-renewed experiment in making its beginning; that it consists wholly in the description of this beginning, and finally, that radical reflection amounts to a consciousness of its own dependence on an unreflective life which is its initial situation, unchanging, given once and for all" [6]. The transcending move to the borders of the of the life-world is an extension to certain unreflective beginnings of philosophical (reflective) experience.

What kind of unreflective beginnings do define transdisciplinarity experience in the most proximate way? Here, of course, various options of comprehension are possible. Lets begin with a description of the specific existential mood, which paradoxically defines a fundamental unity - "unity by mood" (B.F. Porshnev, T. Shabutani). From our point of view, it is due to it that the divergent philosophical and disciplinary approaches to interpretation of reality, personal and craft preferences (forming the stereoscopy of the transdisciplinary research) can be retained in the conditional "frames" of a single research perspective. The unity of the mood creates an opportunity, a prerequisite for communication without a preliminary definition of its theoretical foundation.

The dynamics of human communities is set by the play of the dominant existential mood, defining a specific orientation for each culture between the poles of threat and salvation. The culture and science of the classical era are characterized by a linear disposition to fight the danger embodied in the external nature. At this salvation seems to be found in a rational scientifically based technical control over natural factors.

In modern culture the existential vector of the classical epoch remains, yet it is supplemented by an oppositely directed one. The threat of human existence is diagnosed not only in nature but also in the expansion of techniques and the dominance of objective scientific types of rationality. In this case, salvation seems to come by conservation or restoration of a person's natural environment. At the same time science paradoxically begins to play the role of a savior, and simultaneously, a role of an existential threat.

Thus, transdisciplinarity is based on a constant repetition in the game of hope and fear, their paradoxical convergence in a single human experience causing an existential aporia. Man hopes for a science-based technological solution of his own problems and is afraid of technology, in which he sees both a savior and the ultimate threat. The sustainable boundary for classical consciousness between "*ours*" and "*theirs*" is questionable. Life is grasped by the paradox of the existential mood into a specific integrity. "When we are thoroughly wrapped up in these moods – in which the world of meaning just "is" a certain way for us – we feel ourselves attuned to things in terms of their meaning-giving whole. Each mood has its own way of revealing the whole of things; and such revealing is not just any event but rather is the basic way in which human existence occurs" [7].

Of course, "the whole of things" is not a picture of the world and is not its certain reflecting idea as the object of experience. It is a primary, original puzzle ('enigma' according to V.S. Bibler) concealed in the subsurface of *unreflective life of culture* in its historically special materiality. This puzzle due to the highest existential significance captures a human being, and leads him to search for an answer, it leads to consciousness and puts each individual into the situation of a *responsible act of choice of himself - self-identification.* As we show below, the requirement to identify themselves in terms of conducting a transdisciplinary experience, positions the cogitative in a multiple self-identity of conceptual characters (G. Deleuze).

And already at the level of existential mood a search vector has a different personality and temporal orientation. Depending on what meta-moment the ideal state (norm) is associated with, the whole diversity of possible reactions to a particular existential situation is divided into three conflicting groups. For conservatives the ideal state ("golden age") is localized in the meta-moment of the present-past. Therefore, their response to any threat (moral, political, or environmental) has the form of an antecedent restoration. For progressives the ideal state is localized in the meta-moment of the present-future. Their response to any challenge is a desire to create a new, rejecting both the imperfect and undeveloped ones - all that is brought into the experience from the past. Finally, for realists each situation is presented as a repeat of the previous one. In the structure of their responsible acting, the value of the tactics of restoration or innovation is situationally (pragmatically) determined.

Therefore, whatever real human problem becoming a “subject" of the transdisciplinary research we may encounter - in any case, the language environment of the cognitive-communication strategies will be structured by conflicting positions, which are based on the structure of the temporal value preferences. For example, every time a problem of transdisciplinary risk assessment arises, or that of a threat or the degree of usefulness of a technological innovation, the expert community and the audience are immediately divided into three above described conflicting groups who are unable to reach an agreement at the level of knowledge which is always loaded with personal preferences. They are united by a common basic mood, which, through the use of written and unwritten rules of “language games", provides resolution of the conflict and achievement, of though not understanding (consensus), then at least an agreement (compromise) on matters which touch a chord of each communication participant. The Participant of communication, “stung to the quick" becomes personally responsible for the meaning that he cannot shift on the mediation of any anonymous, collective and general instances. Assistance in mutual understanding arises through recognition of the right of everyone (openness to another) for understanding (creation) of newly preset meanings.

The above-described paradox of the existential mood, structured by the play of temporal and personal preferences, is the first one we found in the course of discussing the conditions of the transdisciplinary experience, directly woven into the dynamics of unreflective life. Provoking and setting up thinking on a particular “wave", it creates some limiting conditions for it, and predisposes to the revival of the already established themes of philosophical and scientific research and to initiation of new ones.

2.3 The Theme of Transdisciplinarity

Let us note that the word “*theme*" was expressed not coincidentally. In our understanding of the knowledge genesis dynamics in the sphere of the life-world we rely on fundamental ideas presented by J. Holton in his book “Thematic Origins of Science Thought”. For us Holton’s approach is important because he is searching for the origins of science in the place where transdisciplinary experience is set - in the structures of the life-world. It is no coincidence he works not only with scientific and philosophical texts, but also with diaries, letters, interviews, laboratory journals and general educational programs. Holton notes that the thematic structure of scientific activity can be considered to be largely independent of the empirical and analytical content of research. It manifests itself in the process of studying the choices that are in principle open to a scientist [8]. Holton’s idea of theming is on the one hand labile enough to hold the internal complexity of scientific experience, its forming nature, and, on the other hand, to express some repetitions (non-conceptually represented universality) in the development of both scientific and philosophical thought.

The paradoxical play of the modern type existential mood imposes repetition of a whole series of traditional themes (which we understand as paradoxes) on sciense and philosophy: of power and vulnerability of the human mind, freedom and determinism, part and whole, reductionism and holism, preformationism and epigenesis, creationism and gradualism, individual and social, natural and artificial, etc. These themes (paradoxes) are proliferating ties of multiplying bioethical conflict plots. In the ever-stretching network of the paradoxes we select three nodes which are most significant for understanding the philosophy of transdisciplinarity: the paradoxical relation of unity and multiplicity, philosophy and sophistry, and the transposition of philosophy.

2.3.1 Unity and Multiplicity

Metaphysical foundation of technological exploration of the world has been a setting for theoretical grasp of some pre-existing in God, nature, reason or transcendental conditions of scientific experience *of the unity.* Multiplicity was perceived as a threat. Awareness of the loss of unity was a cause *making*, according to Husserl's expression, the philosopher think. "Fragmentation of modern philosophy, and its fruitless efforts make us think. Since the middle of the last century, the decline of Western philosophy, if we consider it from the point of view of scientific unity, compared with previous times is undeniable. In setting of a goal, problems and methods this unity is lost" [9]. The modern "thought-provoking" attitude is more paradoxical. It maintains continuity with classical rationalism - philosophy and science can not search for those or other common grounds. Yet, today, in a certain sense, the danger is recognized in the very desire of the 'only' unity, of the only ground. Now the search is carried out to find grounds to justify the "fragmentation" itself, to justify the *objectivity of pluralism* (according to E.A. Sidorenko)[10] and multiple nature of the mind. We are going to cite as examples the concept of culture as a dialogue of cultures by M.M. Bakhtin, the logic of dialogue logic by V.S. Bibler and transcendental empiricism of J. Deleuze. The dialogism (no matter how it is understood) becomes additional (compared to monologism of the classical rationalism) prospect of relations not only to another (reason, understanding, etc.), but also to the other in the form of nature. It is especially well worked out in the theory of self-organization (synergetics). Scientific knowledge is transformed into an experimental dialogue with nature. The "vision of nature is undergoing a radical change in the direction of multiplicity, temporality and complexity"[11].

Ontological foundation of scientific and philosophical approaches, trying to realize the multiplicity of possible unities is a paradoxical idea of "deterministic chaos", shifting the focus from the question of existence to the question of development as the element that generates possible ontological and logical options of order (of the universal). Yet, this shift does not mean "removal" of the question of existence. Two types of questioning are in a tight contact of additional search strategies "*of the law in establishing process and the game of necessity*" [12]. We deliberately emphasized the importance of situations of aporia and paradox in the casus of "bioethics" that are variants of discursive deterministic chaos.

Heraklitus' "polemos" is reigning in the polyphony of becoming and arguing with each other scientific and philosophical perspectives [13]. Such a "polemical" interaction of diverse forces, tied in bioethics into a joint action, may have an unlimited number of variations - from ideological quarrels to synergy motivated by the achievement of mutually beneficial consensus. However, both in this and that case, the "polemicists" *feel the need in each other in order to become themselves.* In the fight they are ‘communicated’ to each other, they are together in it.

However, if neither in God nor in mind or in nature we assume “the eternal law" or the principle of unity which is universal for all, here is the the question - what *can one hope* for when facing acute existential problems? How can communication come without generalization? How is it possible to think *not only the unity of the manifold (the dialectics is quite good at that), but also the variety of possible unities*? The interest of the “bioethics" casus lies in a helpful hint – a spontaneously found vital and practical solution. In response to the difficult life paradoxes arising from the development of biomedical technologies in the 60s we began to form ethics committees that by the beginning of this century have become an institutionalized form of bioethics presence in the structure of the modern type of science. The answer is formed in the context of the joint communicative transdisciplinary effort (dispute or discussion). At the same time, the doctor does not cease to be a doctor and the philosopher does not cease to be a philosopher.

Their expert positions (definitions in the categories of the universal) arise in response to existential aporia, breaking *naive general validity* of ordinary notions about life, death, and human being. They are urgently *needed* for a reasonable answer to the problems identified, yet they are insufficient. They are made sufficient by a joint transdisciplinary effort to achieve through the procedure of public discussion of a generally valid agreement concerning the assessment of unfolding events. The general validity reached by agreement (as if it was universality), for example, in defining the “brain death", on the one hand gives legitimacy to certain biomedical practices (in our example - to those in transplantation), and on the other it provides congruence of confronting disciplinary perspectives in the form of a kind of a *social contract*.

However, no matter how useful the concept of the social contract is, it does not remove responsibility from philosophy for the very philosophical understanding of its participation in the transdisciplinary bioethical communications. We believe that an important step in this kind of thinking is the idea of “unpretentiousness philosophy" belonging to J. Habermas which (and this is essential) is formulated by him in the context of discussion of liberal eugenics projects [14]. What is the meaning of the unpretentiousness of the philosophy of transdisciplinarity? In this case the philosophical search for a universal foundation correlates with communication strategies of detecting general validity in the variety of disciplinary unities. Thus, the setting for universality, matching with the achieved general validity, forms a universe of transdisciplinary discourses.

According to Habermas, the naive identification of own private prospects of discourse with a certain self-evident position of the universal proved its irrelevance in the modern philosophy. The assumption of a universal, one for all existing perspective of truth or idea of the good life, which has recently inspired the philosophical community concerned about loss of “unity", is not just put in question. It is itself, as such, perceived as a threat of an unacceptable interference into the right of every person “to develop ethical self-understanding in order that, in accordance with their own abilities and good intentions to implement in reality a personal concept of “the good life" [15].

Yet, here is a question - is unpretentiousness of mind a manifestation of its impotence? What the philosopher can hope for, unpretentiously proposing judgments, in particular, about the ethical acceptability or otherwise, for example, of liberal eugenics? What can the humanity hope for in the face of existential threats?

In modern democratic secular society references to God are relevant only within the community of coreligionists. In this situation, Habermas offers his variant of "Other" "weakened by proceduralism" as a language or communicative practice. According to Habermas, not only a correct moral judgment, defining the relationship between the subjects, but also the correct ethical self-understanding cannot be obtained by revelation, or "given" in any other way. It can only be won by *joint efforts*" [16] (our italics – L.K.). From this perspective, only the joint communicative effort may give a reasonably well-founded answer to the question about the moral acceptability of the ideology of liberal eugenics, as well as any other issue in transdisciplinary situations. Language as "self-explanatory of human nature" (Marx), presented in the communicative community is a *foundation of our hope* in the face of an avalanche of multiplying existential threats.

By challenging the presuppositions of another, permanent process of nomination, criticism and rejection of failed judgment and selection of successful suppositions concerning the possibility *to be oneself in the face of each other,* the participants of communication are moving towards understanding of the common good, *the basis* of which is the fact of the agreement reached. Yet, the idea of the common good is unusual here, it represents common understanding of how people with different views of fundamental life values can live together. I.e. it is the principle of retention of difference and preservation of polemos as a ground. It is no coincidence that in fact the principles and rules of bioethics are not common "solutions" of problems, but the rules of competition of different value orientations in the space of the public dialogue.

It is natural that the guarantor of the reached "universally valid by agreement" is not some universal logic, but *determination* of communication participants to comply with each other's obligations. The joint effort of moving to the transposition with another in response to his counter-desire *to be implemented together* strengthens the position of philosophizing in transdisciplinary researches and gives the most common answer to the Kantian question - *What can I hope for*? The hope is for that more which is being revealed in a communication community bound in the face of most acute existential problems via the common mood. It is this kind of transdisciplinary communicative community that modern bioethics represents as an idea.

Only in the context of the joint communicative effort the possibility of co-presence is retained in the experience of variety of disciplinary believed unities. What is the relationship between them? We are going to use the discussion of the second theming to clarify this issue.

2.3.2 Philosophy or Sophistry?

The subject of transdisciplinarity can be viewed as a recurrance of the conflict between philosophy and sophistry. And this is such a repetition that creates resources for its new interpretation. As N.S. Avtonomova eloquently writes: "Once in Greece, during the times of the Second sophistry, the philosophy won over rhetoric, the proof - over belief, the objective thought - over achievement of some external goal. In the present situation the rhetoric in the world culture took revenge on philosophy, subordinating its objective aspirations to functional justification. And now, perhaps, it would make sense to return rhetoric to the service of philosophy"[17]. We agree with the relevance of the theme thus posed, yet we consider it to be counterproductive to use the language of victories and defeats. The return of sophistry and its rehabilitation is not a rejection of its “thingness" and “objectivity", yet a desire to find the means to comprehend their forming (disappearing and appearing) character. Testing of “objectivity" and “thingness" projects is held at a public forum of all interested participants, which at the same time becomes a platform for practicing methods and abilities to form their own opinions. This is not a result of lack of respect for truth but rather a discovery of its “human-like" character[18]. The truth reveals its “human-likeliness", as it has been mentioned above, in crisis situations, during failure of established norms, unwritten rules when something alien puts its presence through resistance. “Available means of communication" and rhetorics - reasoning, evidence and demonstration of probability and other techniques are used with the aim to generate by means of language and extra-linguistic means certain emotions and feelings that can in turn lead to new directed formation or modification of the original perception stereotypes and behavior. [19].

The desire of the mind to stand on the God’s point of view stands behind the objectivism. B. Russell in order to express this tradition of philosophy writes: “The free intellect will see as God might see, without a here and now, without hopes and fears, without the trammels of customary beliefs and traditional prejudices, calmly, dispassionately, in the sole and exclusive desire of knowledge - knowledge as impersonal, as purely contemplative, as it is possible for man to attain"[20]. Yet, it is precisely the fact that these points of view can be infinite. Philosophy is a complicating variety of philosophies, each of which offers its own unique project of the world as a whole. Therefore, there is a special need in a human and his private perspective (here and now), the introduction of which is necessary for understanding of the unity of the diversity through keeping of the diversity of virtually existing unities in the experience.

There are powerful resources in culture to keep human and divine, human-like and objective, philosophical and sophistical distinctly and inseparably. It is sufficient to refer to Peter Abelard’s conceptualism in the interpretation of S.S. Neretina, from which we borrow (although in a redefined form form) the ideas of equivocation (bi-meaningfulness) and concept [21]. With regard to the concept we also take into account the approach proposed by Gilles Deleuze and Pierre-Felix Guattari [22].

The idea of equivocation or bi-meaningfulness in our interpretation suggests an immanent two-stroke thought process. It implies that the active role is played not only by reflection determining the specifics of theoretical thought process, but also the intellectual procedure which we would call a “transflection". In our opinion, the transflection is a specific method of justifying the “unpretentiousness of philosophy", which differs from the classical method of philosophical reflection by taking into account the nonlinearity of communication events. The concepts of “non-classical", “synergistic" or “specific" reflection [23] are very close to our ideas.

Metaphysics of the traditionally understood reflection involves a turn, reflection from the object and return of a “ray of light" of the natural mind. Reflection holds that in the subject what (reflection might be such a subject itself) is implicit before the act of its display. The self-identity is the main characteristic both of the being and of the reflexive technique subject aimed at understanding of the preexisting impersonal divine or transcendental true foundation of thinking. The identity of the reflective experience is provided by the idea of pointness of the “cogito” itself and the transparency of the medium (language), in which the cognitive activity is carried out. The transflection implies conversion of a uniform field of reflection, replacing of “I"-spotting or the “subject" of transcendental philosophy with the concept of a sophisticated selfness, implying a multiplicity and immanent presence of non-reflexive, anonymous, incapable of rationalist reduction body experience. In the transflection horizon the experience densifies due to the complexity of the synergistic relationship of the participating agents (cognizing subjects, language, mood, cognitive tools, experience and environment, etc.)

The sense of a classical reflection is a recognition of the identity in oneself (self-identity) and in the other. Therefore, it is inherently retrospective. The transreflection is set by amazement and is focused not on learning, but on "the fundamental meeting" (G.Deleuze) with otherness in itself and the other. In this sense it is prospective and is revealed to the unknown risky future [24]. Otherness is rhythmically structured by the dominant existential mood. It keeps the plan of integrity as a fundamental mystery (problem), whose solution is the aim of transdisciplinary communicative activities of scientists and philosophers.

If philosophical or other disciplinary points of view are self-identical, and like "mental atoms" are reflexively self-absorbed, they do not need any kind of dialogue and, in fact, are not capable of it. They do not need it since they are seeking only the identity in themselves and identity to themselves. Since they are self-sufficient. A different view or a different perspective is just an annoying otherness, which shall always be possible to "remove" after considering it as a particular case, an abstract moment, stage of development, or simply meaningless deviation (error) of the self-identity of the appropriate and true. They are not capable of that since they deprive themselves of a meeting point with another by not recognizing and pushing the otherness out of themselves.

The communication community is based on the mutual need of others in "others" for self -implementation. This is its grounds. The transflection as a *justifying* procedure, is designed to keep a zone of openness to each other and need in each other (tolerance towards oneself and others), to protect against reflexive "withdrawals". Reflection and transflection do not reverse each other. They are in contact, defining (setting limits) and redefining the Kantian question "*What can I know*?".

The fact is that, firstly, in a situation of a real transdisciplinary dialogue the 'I' itself opens a space of possibility to become another - becoming the multiplicity of identities, each of which implies its own form of justified knowledge, which is carried out in the opposition of universal and generally valid. Secondly, my "I can know" includes the result, which can be obtained and specifically justified only in the communicative "together" effort. Of course, I can successfully express an opinion which then will be taken as a universally valid by agreement. Yet, I can not claim to its sufficient justification to be accepted by others from inside the prospects of my specific general (my personal and disciplinary understanding).

Therefore, it is important in the word can to keep not only the cognitive plan, but also a communicative one - I can know what I can tell the other (assuming intersubjective universality or general validity), as well as something more - something that can occur, and it is in that area, where intersubjectivity comes into question. We are going to look at this aspect later when we turn to the issue of transdisciplinary translation.

Next (and this results from the previous one), the "I can know" includes a condition of communicative competence (K.-O. Apel). It marks the feature of such knowledge which is possible to use as an argument in a dialogue with others as opposed to the knowledge, which I just know, but I can not use. It is especially important for bioethics. Theoretically people, such as patients, can know about their rights, yet they do not have the knowledge-skill to implement these rights in real social interactions.

If the expressive tool of reflection is a notion, then the transflection as a method of the unpretentiousness philosophy works with *concepts*. They are forms of a thought operating in the mode of direct dialogic communication of a speaker and listener, a writer and a reader. This is particularly evidenced by the Latin etymology of the word "concept", which is derived from the prefix "con" (to act jointly, to interact, be compatible) and the root "cept" (take, accept, get).

From our perspective, the existential energy of the aporia of life incidents (casus) and the paradoxical experience of their comprehension is concentrated in a variety of paradoxical problem nodes - concepts as germs of thought ("dispute" - V.S. Bibler). For example, the development of heart transplantation techniques identified the concepts of 'life' and 'death' as being such a problematic node (the subject of the transdisciplinary dispute). The meaning of the paradoxical situations that arise in connection with the progress of new reproductive technologies (abortion, in vitro fertilization and embryo transfer, cloning) is concentrated in a specific bioethical concept of "human" (T. Sidorova). The paradoxes of the new models of relationship between doctors and patients are embodied in the "personality" concept. The concept links the spheres of life and thought in a speech, pointing to a possibilistic (V.S. Bibler) nature of their correlation, but not leading this possibility to complete actual "intake of the idea of being, or the thought being" leaves as a significant the *uncertainty, fundamental mystery (paradoxicality), which actually forces one to think*. It is rhythmically structured by the play of the dominant existential mood.

The concepts common to the whole field of transdisciplinarity provoke diversity of scientific research areas which are aimed at finding philosophically, theologically and disciplinarily *justified* solutions having the form of *conceptual* seizure. However, the paradoxical complexity of existential problems is that (as it has been already mentioned) none of the disciplinary reasons even if it is *necessary* can claim to *sufficiency*. Both in the question of the beginning of human life, and in the question of the final moments of human existence, and in other less acute existential situations the polemos is reigning, shrinking the diversity of minds (scientific, philosophical, religious), truths and ideas of the good, understandings of the truth of human existence into the aporia of a single space of the dispute. The concepts, being extended by paradoxes of conceptual seizure, generate a paradoxal momentum for finding the roots and validity in the field of transdisciplinary communications of the life-world.

Thanks to the transflection retention (seizure) of "more" as a fundamental enigmacy (unreflexive), the concept, as a form of dialogical speech, preserves an open space for *another* as a fundamentally *different*. In it, as in an "embryo" of the thought, "the makings" are always presented, embodied in the speech of at least two participants of the dialogue, their original argument - polemos.

In contrast with the definiteness of the notion, the concept (due to its paradoxical nature) is initially underspecified. For classical thinking uncertainty of cognition and mutual understanding had 'subjective' character of the intelligence insufficiency. In modern science and philosophy it becomes "objective", pointing to formation as to an intrinsic property of the reality itself. The concept is "living" in the between-speech of those holding a conversation, inseparably and distinctly reproducing in itself subjective and objective aspects of the interlocutors' speeches, as well as reproducing the more retained by the transflexion. For this reason it is acting as an indispensable "intermediary" of the dialogic communication or "communicating without generalization" of the transdisciplinary communicative translation experience, localized in the border zone between the language of everyday life (the word) and disciplinary discourses (the notion).

Here we are approaching the next important distinction between the notion and the concept. The logically related scientific theory (or theoretical model) is an expanded form of the notion. Intra-disciplinary, binding the paradoxicality of the notion-catching (possibility of alternative theories), the concept is unrolling into the conception [25]. Within philosophy (its special areas such as ethics or anthropology), theology, biology, medicine, psychology, and other disciplines, the conceptions of person, personality, death, life, etc. are formed driven by the energy of concepts.

Concepts take the form of *conceptual narrations* in the transition to the transdisciplinary communications field. Unlike conventional narrations structuring relationships in the life-world, the ties of the conceptual narrations and their vicissitudes structures include the above marked existential aporias, paradoxical semantic clots of which are precisely the concepts [26].

In the transdisciplinary communicative practices the speech of an expert represents a between-speech of at least two speeches – the first one is a disciplinary-oriented logical statement of objective truth, the other one is focused on the rhetorical (through the narrative presentation of the situation) conviction of another. At the same time, if disciplinary discourses are self-closed, in narrations their unlocking occurs towards each other. P. Ricoeur, discussing the problems of the dialogue of Sciences and Humanities concerning understanding of the nature of human action, indicates that the narration is a natural “high-level meeting place" *for dialogue* (dispute) of the diverse options of the moral and theoretical reason [27] . This is achieved by a possibility of translation of the disciplinary knowledge into the language of narrations that simulate possible projects of human existence in the structures of the *life-world* in the form of results of research or their moral evaluation.

The transdisciplinary communication being a *mediated* translation of disciplinary knowledge into the language of narrations, models specific forms of common life activities of individuals trying to resolve existential paradoxes packed in the concepts. For example, a scientist (biologist), who invented a new technology, shall (in order to get the message meaning of his discovery across non-specialists) translate their results into the language of the life-world narrations. Thus, he seems to be forced to expand the scope of an *experimental dialogue* with nature, moving the *dialogue itself* into the experiment to harmonize his positions with the moral positions of other subjects [28]. Simplifying, we can say that he needs to present his discovery through the narration-expressed versions of new prospects for solving specific human problems: treating diseases, making life easier, improving quality of environment, etc. Exactly in the narration-structured environment of the life-world, the existential aspirations of scientists and their assumptions about the meaning of good come into conflict with the completely different aspirations and assumptions of other participants in social interaction. Vital-practical tragic aporia arise (as noted above) and are condensing in the concepts.

It is these primary narrative representations (nodes and plot strings of which the concepts are) which philosophers, lawyers or psychologists start to work with. Based on the narration as on the original empiricism, they (each in their own way) conduct professional research and, thus, translate them into specific languages of specific disciplinary areas. As a result of these studies they may come up with their own interpretation of the meaning and moral value of the scientist’s discovery.

However, the clarity of judgment of a philosopher, psychologist or any other expert to others (non-experts) again can only be achieved as a result of the reverse translation of the results of philosophical, legal or psychological analysis into the language of narrations of the life-world. The meanings and evaluations identified by them shall be retold as open or closed versions of life stories which are possible as a result of implementation or non-implementation of biomedical technologies (for, example, permission or prohibition of human cloning).

In this sense conceptual narrations, representing the life-world structures, are transdisciplinary communication mediums. Concepts are the sources of meanings generated as a result of direct and inverse translations. Transflection keeps non-linearity of the dialogue in a variety of concepts, highlighting contingent islands of stability (validity by arrangement) in the formation and exchange of meanings and maintaining a productive zone of mutual untranslatability. At the same time the mutual untranslatability of languages used be transdisciplinary communication partners (unsolvability of fundamental paradoxes) is valuable as a sense-generating zone. As Y.M. Lotman emphasizes: "Value of a dialogue turns to be connected not with that intersecting part (the intersections of the speaker's and listener's language space - L.K.), but with the information transfer between not intersecting parts. It places us face to face with an insoluble contradiction: we are interested in communication precisely in the circumstances which make communication more difficult or even impossible. Moreover, the more difficult and inadequate translation of one of the non-crossing parts of the semantic space into the language of another is, the more valuable becomes the fact of this paradoxical communication in information and social terms. One can say that the translation of what is not translatable is a carrier of information of great value" [29]. The act of thinking which is carried out during this kind of translation is an option of the transflection discussed above.

In the above analyzed interamnian of transdisciplinary communications voices of a philosopher (in its classical sense) and a sophist are only situationally distinct self-identities of inner and outer speech of a real philosophising individual, whose specific position (trans-position) we are going to consider now.

2.3.3 Transposition of Philosophy

Let us distinguish three possible thematic positions of philosophy in relation to the experience of transdisciplinarity, taking into account the way they unfold in the casus of "bioethics". These positions determine the 'place' of a thinking person and his self-identity which, following Gilles Deleuze and F. Guattari, we are going to call a conceptual character. First, we note the position of a detached Observer, which is historically assigned to the modern European philosophy. Philosophy is *thinking* about the transdisciplinary as an object existing in the context of a new type of science. This form of a reflexively established self-identity of a thinking person is characterized by paradoxical positioning - to be outside the world (this allows to understand it as a whole) and in contact with it, on its border. When, for example, Descartes, methodically questions *everything*, and escapes from *everything*, his only task is to find the absolute foundation of meaningfulness of all this everything. His individual effort of a single human being opens up a universal associated with a divine point of view.

The feature of the theming is, in this case, that the human effort is being eliminated from the result - an integral vision of the world. It does not have an ontological status and refers to the empirical visibility. In this respect, thinking about the transdisciplinary does not change anything in the subject of the thought. Any *reasoning* about genes, clones, organs, moral principles or rules naturally reproduces this transposition of a self-identity of a philosopher or a scientist in a situation of transdisciplinary. There is a notion about the uniqueness of the universal (the truth) in its basis, claiming both for the integrity and the universality. This is a basic and reflexively justified position of the disciplinary knowledge, from which the expert idea is put forward by concepts into the situation of the transdisciplinary dialogue and to which they keep coming back for the purpose of conceptual seizure of the unfolding events.

The second form of the transposition of philosophy is congruent to the position of the knowing mind in the non-classical science (V.S. Stepin), for which the effort of the learning individual, objectified in the language and instrument, becomes observable itself. The objectivity of science gains features of the human presence and the subject of its research acquires people-dimensionality [30]. We mark this position as a position of the Participant. The philosopher is not only thinking about bioethics, yet he becomes himself an active participant of the transdisciplinary communications. His thought, his effort as of a real individual, is an event changing the condition of the object of his thought.

In the transdisciplinary experience the objectivity of disciplinary areas is marked at the time of formation, experiencing a reincarnation of its own beginning, and therefore it appears as unstable (appearing and disappearing) [31, 32]. Correlatively the self-identity of the Participant is also unstable and is formed along with the objectivity. But precisely in this unsteady transient transdisciplinary state the scientific disciplines become open to a meeting with other forms of disciplinary scientific knowledge, religious experience, and 'applied knowledge' (M. Heidegger).

If we use the scheme of a subject-object relation, in this case the classical form (first form of the philosophy transposition) is radically complicated by the variety of ways of interaction paradoxically presented in it. Universal definitions of disciplinary knowledge can no longer claim to integrity and universality of understanding of the happening. To achieve it, the diversity of the universal is extended by "as if the universal" – the generally valid, achieved as a result of cognitive and communicative practices of transdisciplinarity.

Transflective retention in concepts and conceptual narrations of a large enigmatic transdisciplinary experience is turning the border between the learned and not learned, between what can and what cannot in principle be scientifically known, into a communication channel with other forms of the mind (for instance, religious) and other forms of spiritual experience.

Retention of dual understanding of this transposition is a paradoxical event. The Participant of transdisciplinary communications regulary becomes an Author producing in the word and in the deed results of his observations, or a Hero of his own judgments (narrations) about transdisciplinarity as a possible object of a thought. He is both the one *responsible* for his choice, claiming to the universal, and the one who is already tragically inscribed into a specific situation, defined by generally valid values and personal preferences. He is inside and outside, he is free and to the same extent determined and defined in his decision by something external or some mysterious inner freedom. At the same time the Participant for himself and for another plays a paradoxical role of complementarity characters of conceptual narratives - of an Expert and an Outsider.

It is in this variety of paradoxically presented ways of interaction analyzed in this transposition, where each participant, leaving the scope of his private position (including the disciplinary one) in the transdisciplinary experience is a potential philosopher. Interpretation of these circumstances, in fact, refers to the third transposition. Yet, still it is naive. Human (universally valid) and divine (universal) enter into a complicated game to comprehension in the third position. A disciplinary philosopher, after going through the transdisciplinarity practice in the “bioethics" casus, enters the third transposition.

The third transposition of philosophy, which we denote with the word Witness, as it seems to us, is an embodiment of the philosophy of transdisciplinarity phenomenon as such. Keeping connection with a vital and practical casus, advancing into the transdisciplinary experience under the imperative pressure of concepts, turning the answer in the conceptual universality of the Observer and contextual validity of the Participant, the Witness constitutes himself as the one who keeps the *distinction* (polemos) of the two above mentioned conceptual characters and provides the experience of their bound execution. He keeps the original paradoxical feature (deterministic chaos) of the transdisciplinary experience, which, as causa sue ensures its constant repetition in multiple existential situations generated by biotechnological progress.

Each of the trans-positions is characterized by its own “voice" or, to be more precise, by its own “speech". Speech of the Observer strives to turn into a logically connected reasoning, expressing some true state of affairs. The truth is the alleged basis of this position. In terms of expression the Observer becomes an other conceptual character - Subject. The speech of the Participant, without abandoning the intention for the truth, brings into the situation an element of relativity, dependence on a private (individual) decision of the observer, which itself is not justified and quite accidental. Such conceptual characters as Author, Hero, Reader, Expert, and Layman constantly appear and disappear in this equivocal speech. The Witness’s speech, keeping the truth attitude as a basis, and taking into account the relativity and multiplicity of truths, introduces its own act of witness (attestation according to Paul Ricoeur) as a justifying one through personal identification in a responsible act. The Universum of the Witness’s judgments is unrolling in a paradox of two simultaneously present limiting assumptions of “universal" and “generally valid". In a very strict sense, the Witness is a one who as a unique human individual, evidences the reliability of the “divine" and general validity of the universal. And the strength of this evidence depends not only on the truth open to it, but also on Witness’s luck to get two gifts of real existence - attention and recognition of it by others. [33]. These others - there is a communicative community, which in respect of evidence plays the role of the Judge, whose decisions are taken in a joint communicative effort. This is the meaning of the transposition of the unpretentiousness philosophy in our understanding. Naturally, a product of a special kind should be an embodiment of this experience of philosophizing, which we call the open one[34]. To be open in the sense of the inherent incompleteness, addressing the search for *self-justification*, to the really other, as to the other Witness, and Judge.

By playing the Witness’s role, the philosopher is trying to track events of emergence and interaction of two above mentioned positions and of himself in this interaction. Significantly, the transposition of the Witness is pinpointed just before, in the border situation of the act of a responsible choice, and is not just a choice of a particular action (that’s his business as a Participant), but also the choice of the “self" as responsibly (in reply to the question raised by an existential situation) acting in a given place and time. The transposition of the Witness inherently contains the ethical dimension of the ambiguity of the choice. What answer may be given to the Kant’s question “what should I do?" in such a situation? What kind of responsibility is meant? Obviously, in paraphrasing Deleuze phrase, we can answer that in order not to be responsible *for* the victim, it is necessary to simultaneously hold the responsibility *towards* them.

Let us make some conclusions by summing up our arguments. Firstly, in contrast to the classical science, which is ideally a closed system, the transdisciplinary experience is a new form of production and generation of knowledge as an inherently open system. Traditional forms of disciplinary scientific knowledge are generated in this experiment along with a wide range of common, religious and other forms of knowledge. In addition, all these forms are associated in the framework of the universal knowledge achieved by a joint effort, associating and keeping more, the variety of universal definitions and the generally valid by agreement. Secondly, the conditions of possible transdisciplinarity experience are: casuses of life-practical situations, paradoxical play of the existential mood, a wide range of thematic paradoxes, network of concepts and suspension of conceptual narrations, as well as three major transpositions of philosophizing, which the network nodes (conceptual characters) of the philosopher self-identity are arranged around.

Due to the border nature of the transdisciplinary situation these conditions both precede an experience and are newly redefined in it, and become different (being generated in a certain sense). From our point of view the conditions of the possibility of transdisciplinarity experience (in its philosophical and scientific aspects) considered in such a way, appear in the form of a network of paradoxes. It operates according to the causa sue principle, constantly renewing (provoking) cognitive and communicative practices of the transdisciplinarity (the “production" of knowledge).

The philosophy of transdisciplinarity, slightly adjusting Nancy’s statement, when still thinking about questioning, continues to think “about the answer: though not about the response-decision or the response-verdict, but about the co-communication. In co-communication which is our co-responsibility, we do not need someone who impedes the communication, but on the contrary, who establishes it and gives a new impetus” [35].

In the situation where humanity is once again losing its unity, internal stability, and finds itself in a threatening and fascinating abyss of chaos and where a wave of new *barbarism* is scouring its cultural base, the transdisciplinarity experience, and this is what we tried to prove, sheds the light on the positive meaning of the current existential crisis situation, in which culture refers to its own *flesh* and the *matter of re-creation* [36] .

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CHAPTER 3

From Discipline to Inter-and Transdiscipline in the Environmental Academic Sector in Mexico

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In the present work we outline the history of environmental policy and institutions through a timeline, in which we observe the advances that Mexico has made in this area, some of them due to international situations. The response to these obligations requires the training of specialists in the subject, who will advance from a purely sectorial (disciplinary) vision through multidisciplinary work to a transversal (transdisciplinary) conception, at least on paper. However, this was not possible due to the priorities of the Mexican governments of the twentieth century, now it is proposed to move towards this interdisciplinary work in the environmental sector through a series of policies whose results are shown, through an exploratory deductive study.

Keywords*:* Transdisciplinarity, Mexico, Environmental Sector, Sustainability, Education.

3.1 Introduction

During the 1800s, the Mexican territory was composed of 5 million km^2 with a population of 5, 837,100 inhabitants, reaching from the Isthmus of Panama on the South, to Oregon on the North. Due to the political instability in the country, more than 60% of the territory was lost, currently the area is 1, 964.375 km^2 with a population of 112, 106.672 inhabitants. This leads us to reflect that more natural resources are lost through politics than through natural phenomena, not only in Mexico's past but also in its present [1]. In this chapter we have decided to contextualize the discipline, interdiscipline and transdiscipline through the evolution of the environmental policy and institutionalism in Mexico, as well as the study of the incorporation of environmental issues in the universities of the country and the advances in interdisciplinary work. The above is exemplified with an interdisciplinary center and its academic activities in the environmental sector as a result of the orientation of policies in science and technology.

3.2 Historical Overview of the Environmental Research in Mexico

The environmental sector in the history of ancient Mexico is shown as a harmonious and respectful relationship through the poems of Nezahualcóyotl, King (tlatoani) of Texcoco in 1402. The knowledge that the ancient inhabitants of Mexico had are as different as astronomical, agricultural, commercial and architectural, which allowed the construction of aqueducts, botanical gardens, agricultural cycles among others; during and after the conquest of Mexico by the Spaniards. The management of natural resources was carried out through the ordinances of the Motherland, which referred to the measured use by the locals, in contrast to the exploitation and export by the Spaniards. Among the professions that arrived together with Hernán Cortés, which impacted because of their activities, were: the founding doctors of the task of public and private health, the religious who were in charge of the evangelization of the natives, the foundation of art and trades schools and the clerical, the miners who made the first expeditions to the volcanoes and mountains for the extraction of minerals, and the lawyers and administrators who came from the schools of Salamanca, Valladolid or Alcalá [2] [3].

The Spanish Crown created the Royal and Pontifical University of Mexico by Royal Decree on September 21, 1551 and the organization of knowledge in the colonial University followed the traditional model of European medieval universities: with four major faculties which are Theology, Canons, Laws and Medicine and a minor Arts. There they were formed, especially clerics and also the members of the incipient New Spain bureaucracy. At the end of the 18th century, the Mining College and the Botanical Garden (1772) were created. When the Independence was achieved, the schools of San Ildefonso, San Gregorio, San Juan de Letrán y Minería, the School of Medicine, the San Carlos Academy and the Military School emerged [4] [5].

Because of the nascent university, the conditions were created to form a minority of literate able to perform the middle positions of the state and ecclesiastical bureaucracy, instead of the Creoles having to go to Spain to obtain such training, or that, due to the lack of qualified personnel in Mexico for such administrative positions, all of them had to be provided from Spain, and with individuals of peninsular origin [5].

After the Independence of Mexico (1810) and the readjustments of a new nation, the Superior Health Council was created in 1841, which consisted of five full members: three were doctors, one a pharmacist and one a chemist. Its task was to monitor the correct practice of medicine and pharmacy, to carry out health actions for the benefit of the population and to carry out studies of various epidemics and mortality statistics. Likewise, it was in charge of legislating the surveillance of cemeteries, schools and workshops, said council was attached to the Ministry of Health [6].

The evolution of the environmental policy in Mexico was taking place as the country developed in its economic activity, in its population increase and in international demands. Initially, its focus was purely health, in charge of health professionals, whose approach to knowledge was to improve the sanitary conditions of the natural environment of the population, while continuing to exploit natural resources for export. It was in 1917 when the environmental policy was written for the first time in the Constitution of the United Mexican States; it was determined that ownership of land and water belonged to the nation and that public interest was above private property. Another important aspect of this was the distinction between the soil and the subsoil, which resumed the dominance of the subsoil for the nation [7] [8].

The professions that were added to address the environmental issue, apart from doctors, chemists, pharmacists, were lawyers and economists; with the issuance in 1940 of the Regulation for commercial, annoying, unhealthy or dangerous industrial establishments. This regulation was directed mainly to the industrial sector, which had a great support for its development, however, it had already become clear the pollution that this sector generated, reason why this regulation prohibited the discharges of industrial waste hazardous for humans, animals and agriculture, required in industrial establishments to treat substances in order to control emissions into the atmosphere. The above said regulation was issued by the Ministry of Economy.

In 1940, Mexico joined the Convention for the Protection of Nature and Preservation of the Wildlife of the Western Hemisphere. As a result, a series of regulatory guidelines was created, including the Forestry Law and the Law on Soil Conservation and Water (the latter being the first of its kind in Mexico, where it was expressly stated that prevention of soil erosion and flooding was of public interest). In 1947 there was a reform of the Forest Law where forest reserves and protected areas in the hydrological basins were established to protect the irrigation and electric power systems, decreeing total bans in the forests of the center of the country to guarantee their recovery. In this stage the professionals who took rise in the environmental sector were the agronomists who left the common pattern of going to train in France or European schools and went to the United States to learn techniques of soil conservation, a priority that had been set government.

From 1969 the environmental legislation focused on the prevention of pollution, promulgating among the regulatory framework the Federal Law to Prevent and Control Environmental Pollution, the Regulation for the Prevention and Control of Atmospheric Pollution originated by fumes and dust, the Regulation for the Control and Prevention of Water Pollution, Regulation to Prevent and Control Sea Pollution by Dumping Waste and other Materials. The professionals involved in the growing regulation were civil engineers, chemists, hydraulics, foresters, agronomists, biologists, lawyers, economists, architects and urban planners [8] [9] [10].

In 1972, the United Nations Conference on the Human Environment, held in Stockholm, Sweden, was convened by the United Nations Organization; It was the first major conference on international environmental issues, and marked a turning point in the development of international environmental policy; as the way to analyze environmental problems from an interdisciplinary perspective.

For Mexico, it influenced the creation of environmental institutions such as the Under secretariat for the Improvement of Environment, which would address environmental issues, with a priority to address pollution problems, the creation of the General Directorate of Urban Ecology (1976), the Inter ministerial Commission for Environmental Sanitation (1978), Ministry of Fisheries and the Secretariat of Urban Development and Ecology SEDUE (1983), with professionals in the different branches of engineering in the different institutions. In 1987 the meeting of the World

Commission on Environment and Development of the United Nations was held and the report "Our Common Future", better known as the Brundtland Report, was published. The document suggests that countries should adopt population control measures, guaranteeing basic health, education and housing needs; food safety; access to drinking water and sanitation; conservation of biodiversity and the reduction of fossil fuel consumption, encouraging the adoption of renewable energy sources [8] [11]. In response to the Brundtland Report, Mexico issues the General Law of Ecological Equilibrium and Protection of the Environment, LGEEPA (1988), which makes a competent distribution of environmental matters between the federal government, state entities and municipalities. It is situated beyond the environmental notion as a problem of pollution which poses it as a problem of natural resources, its proposal is that of an integral perspective, it appeals to the environment and its multiple interconnections with factors of natural order and social nature [8]. In the first instance, a multi-institutional-multidisciplinary participation is sought to address the environmental sector.

In 1988 the Intergovernmental Panel on Climate Change (IPCC) was created to provide comprehensive assessments of the state of scientific, technical and socio-economic knowledge on climate change, its causes, possible impacts and response strategies. Among the professional participants who had been participating in the environmental sector were physicists, sociologists, geologists, geophysicists, oceanographers, to provide disciplinary options against the phenomenon of climate change.

In 1992, the United Nations Conference on Environment and Development was held in Rio de Janeiro, Brazil, and in Mexico the National Institute of Ecology was created as the institution that would address the environmental issue as a whole and be able to issue the policy for Mexico, with the support of the Federal Environmental Protection Agency (PROFEPA), which would monitor compliance with this environmental policy. Also in 1992, in addition to INE and PROFEPA, CONABIO, the National Commission for the Knowledge and Use of Biodiversity, was created. The professionals who headed these dependencies were biologists, with international postgraduate degrees, some of them in ecology.

In 1994, with the signing of the North American Free Trade Agreement (NAFTA) and the entry of Mexico into the Organization for Economic Co-operation and Development (OECD), there was a strong increase in the country's economic activity. creation of institutions equivalent to those of their counterparts, for example the Secretariat of the Environment, Natural Resources and Fisheries (Semarnap) was created, led by a biologist whose mission was to raise the range of the national environmental policy by bringing together various bodies with environmental attributions In a single secretariat and incorporating the notion of sustainable development, it was constituted as the authority in environmental matters with competence in water, hunting, fishing, air, forests and environmental issues in general. The INE became his intellectual arm where academics began environmental research.

In 1996, the LGEEPA was reformed, where environmental legal aspects were incorporated, adding self-regulation, voluntary environmental audits, inventories of pollutant releases and transfers and the unification of procedures for operation and functioning of labor competency establishments. It incorporated guidelines derived from international conventions and adscription to international institutions such as the OECD and the term: the polluter pays, it also include economic instruments and decentralization. It let the environmental policy had a self-management approach to encourage the industrial sector to comply, so the professionals in the industries were in charge of the departments of Safety and Hygiene who handled everything related to the environmental sector, most of them were mostly engineers who received complementary training in the environmental area, through courses and diplomas. After Mexico signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 as part of the agreements, in 1997 Mexico's first national communication on climate change was released. It consisted of an emissions inventory of greenhouse gases of 1990 and the first studies of the country's potential vulnerability to climate change. With the above, Mexico began to change its environmental policy, orienting it towards the demands of the international climate change policy. On June 9, 1998, Mexico signed the Kyoto Protocol, and the Senate of the Republic approved its ratification on April 29, 2000 [11].

The Semarnap in 2000 changes to Semarnat (Secretariat of Environment and Natural Resources) with three undersecretaries:

1. Planning and environmental policy.
2. Management for environmental protection.
3. Fomento a la normatividad ambiental.

Institutions are created for environmental control:

1. National Forestry Commission (CONAFOR) 2001.
2. National Institute of Forestry, Agriculture and Livestock Research (INIFAP), 2001.
3. National Commission of Natural Protected Areas (CONANP) 2002.
4. Interministerial Commission on Climate Change (CICC) 2005.

Although the dependencies are headed by disciplines such as biology, it is a fact that with the creation of different institutions the integration of several disciplines was sought, an interinstitutional-interdisciplinary work is attempted, between the disciplines of the natural sciences and the disciplines of the social sciences; the reflection would lead us to think that if Mexico had had interdisciplinary personnel in the environmental sector, it would not have led to the creation of multiple environmental dependencies that duplicate functions and atomize resources.

In 2001, reforms were made to the LGEEPA in relation to the construction of the program to promote Sustainable Development in the Federal Government, the Transversality Agendas of Public Policies for Sustainable Development are made. Collaborating with: the Secretariat of Agrarian Reform (SRA), the Secretariat of Agriculture, Livestock and Rural Development (SAGAR), the Secretariat of Communications and Transportation (SCT), the Secretariat of Economy and Industrial Development (SECOFI), the Secretariat of Social Development (SEDESOL), the Ministry of Public Education (SEP) and the Ministry of Health (SS).

This represented a great advance for the environmental sector, the institutional proposal of transversality, invited Mexico to respond with its social capital to transdisciplinary works. In 2002 the Johannesburg Summit was held in South Africa, it was a meeting where the determination to work towards sustainable development was reaffirmed. Where the priority measures required for sustainable development were established, encouraging governments, civil society and companies to present initiatives to establish collaboration agreements to improve the living conditions of people around the world [11].

As a result of this meeting there were advances and modifications in the regulatory framework of the environmental sector in Mexico, including the LGEEPA (it modified articles 19 on the territorial ordering of human settlements and their natural environment, environmental impact, Art. 51 related to the Areas Protected Naturals), and the 2007-2012 Sectorial Program for Environment and Natural Resources (PSMARN) was created, which establishes the set of sectoral, strategic objectives and goals through which the sector will meet the objectives and strategies defined by the National Development Plan in Environmental Sustainability, which was distinguished as a fundamental axis in sustainable human development.

The current 2013-2018 National Development Plan stands out for the recognition of the need for joint actions and commitments between the different levels of government and for the objectives of environmental preservation; however, it is worrisome that the concept of sustainable development has disappeared. As of 2012, the environmental policy was subscribed to the attention of the agreements of the United Nations Conference on Climate Change, the General Law of Climate Change was issued, published on June 6, 2012; the National Communications of Mexico on Climate Change are issued where the national inventories of greenhouse gas emissions are updated, the scope of the General Law of Climate Change is specified, and the advances of the programs to mitigate climate change and in the integration of the topic of climate change in the social, environmental and economic policies of Mexico. The participation of the professionals is based on the adaptation of the methodologies issued internationally for the measurements of greenhouse gases through mathematical modeling of atmospheric and maritime processes that represent in graphical forms the increase in temperature, the increase in the level of the sea, etc., at first the physicists, geophysicists, meteorologists, have displaced the other traditional professionals, leaving the social sciences far behind in their various disciplines facing the study of environmental policy and climate change.

"Rio + 20" is the abbreviated name of the United Nations Conference on Sustainable Development, held in Rio de Janeiro, Brazil (June 20-22, 2012), twenty years after the historic Earth Summit in Rio in 1992. Rio +20, the world leaders, together with thousands of participants from the private sector, NGOs and other groups, came together to shape the way in which it can reduce poverty, promote social equity and guarantee the protection of the environment on an increasingly populated planet. The two main themes were: how to build an ecological economy to achieve sustainable development and lift people out of poverty, and how to improve international coordination for sustainable development.

The Mexican environmental policy has been blurred to move from a national policy to an international policy, framed by all those international demands on measurement, mitigation, vulnerability to the phenomenon of climate change; everything that had been gained within the federal public administration on discipline, multidisciplinary, interdisciplinary, institutional trans-disciplinary environmental sector, even on paper, is falling into an inaccuracy of responsibilities between international agencies and national government, a situation that could certainly leave local environmental issues aside.

As a conclusion to this first part we could say that the answer in question of trained human resources for the environmental sector was exceeded, with the institutional changes in the sector, from the 19th century until the end of the 20th century, it was tried to follow up with professional disciplines, initially trained in European schools, until Mexico was able to create its own human resources. However, always behind the progress that was made in the construction, modification, institutional innovation in this sector, partly driven by international agreements;

undoubtedly, it was an opportunity for the academic sector from the universities to grow and respond to these advances. However, this was not the case, the lack of human resources prepared in the sector has led Mexico to take wrong decisions. We dare to say that the lack of trained personnel allowed the privatization of the environmental sector, leaving the responsibility of environmental policy to international organizations.

3.3 The (Tardy) Response of the Academy to Changes in the Environmental Sector

The different stages through which Mexico passed through during the nineteenth and twentieth centuries, tell us about a process based mainly on the exploitation of natural resources, the industrialization of the country, and the creation of institutions and universities, to achieve a "stabilizing development".

The changes in the population of our country with accelerated growth, the urbanization process, protectionism and the policy of import substitution meant that in less than 30 years the country went from being predominantly agricultural and rural to being industrialized and urbanized.

Within its system of higher education, the university, which could be considered modern, was founded in Mexico. In 1551, when the National University of Mexico was opened, several of the existing schools (located in Michoacán, Yucatán, San Luis Potosí, and Guadalajara) were incorporated to the University that in this way became the main training institution for professionals. As of 1916, several Technical Education Schools were created that depended on the Secretary of Public Education that culminated in the founding of the National Polytechnic Institute (1936). In 1948 the Regional Technological Institutes were founded. Thus, the aforementioned institutions, together with private institutions, are part of Mexico's higher education system and are in charge of training the professionals in demand for the development of the country; however, this system in the public sector continued to operate until past the mid-twentieth century with the same programs with which they were created, without curricular updates, representing a delay in their programs compared to the demands and requirements of the country. It gives the impression that the rulers thought that sowing educational institutions throughout the country was enough and that these alone were going to be renewed and were going to be generating knowledge and professionals at the same time that the country was growing. At the beginning of the sixties there was an educational impulse, to call it somehow, by President López Mateos, with the creation of a financing and subsidy policy to the UNAM and the Universities of the States. However in the following administration Chaired by Gustavo Diaz Ordaz (1964-1970) priorities changed as well as the way to exercise power. For him, the educational institutions represented a great budgetary burden and a benefit that had to be revised because it could not be for the whole population, so the decrease in financing to the universities began.

The Mexican universities are a sample of how the backwardness in the economy and the petty interests of the class of an oligarchy are reflected in the culture of the country in question. Our universities, many of them with great and ancient traditions have evident lack of the elements essential for any university due to the scarcity of budgetary resources and the existing disorder [12].

The authoritarian government did not accept the demands of the middle class to participate in the political life of the country, the abandonment of higher-level schools (low salaries to teachers, no scientific research, deterioration of infrastructure) political control of workers, peasants and workers in general, through anti-democratic and intolerant corporate organizations, non-existent freedom of expression and press, among other characteristics, made it possible for the university to become an alternative political space for the democratic struggle. Indeed, the universities, sheltered in the autonomy (product of the anti-authoritarian struggles against the Mexican State of the Thirties), were practically the only social space where dissidence and free thought could be expressed [12].

The promises that had been made after the Mexican Revolution of 1910 were forgotten, followed by inequality, misery, insalubrity, ignorance, injustice, all wrapped up in an apparent development of the country. Towards the end of the 1960s, universities had their lowest level of relationship with the State. They were socially recognized as a problematic focus, they had become the alternative spaces of response to the regime, they did not enjoy finances that allowed them to develop and expand according to the pressures of student demand, and the above is culminated with the Tlatelolco massacre, where the official repression reached limits never seen before.

During the presidency of Luis Echeverría Álvarez (1970-1976), the situation returned to an apparent calm. The conditions for a general process of modernization of higher education weregiven with the aim of “healing their wounds” [5]. New schools werecreated within the two largest public universities in the country, for two reasons: because of demand and as a strategy for the rigidity to change existing schools; in the National Autonomous University of Mexico: the Colleges of Sciences and Humanities (CCH’s) and the National Schools of Professional Studies (ENEPs); within the National Polytechnic Institute is created the Interdisciplinary Professional Unit of Engineering, Social and Administrative Sciences (UPIICSA), and the Interdisciplinary Center of Health Sciences (CICS), as well as in the subsequent years the Interdisciplinary Research Centers for Integral Development Regional in Durango, Michoacán, Oaxaca (1980); the Interdisciplinary Center for Research and Studies on Environment and Development (CIIEMAD) (1996), the Interdisciplinary Professional Unit of Biotechnology UPIBI (1987) and the Interdisciplinary Professional Unit of Engineering and Advanced Technology UPIITA (1996).

Other of the higher level institutions that were created wasthe Colegio de Bachilleres and the Universidad Autónoma Metropolitana (UAM) (1970’s).

This reform in higher education had an emphasis on transforming existing disciplines or creating new disciplines through systematized and permanent making of research tasks. As a result of this modernization, the range of careers related to the environment was expanded, such as: Environmental Engineering, Energy Resources Engineering, human settlements design, hydrological engineering, mechanical engineering, electrical engineering, industrial engineering, bioengineering, social anthropology, biomedical engineering , physical engineering, metallurgical engineering, chemical engineering, hydrobiology, experimental biology, animal production, among others that being traditional careers were given novel approaches with the insertion of subjects that had an interdisciplinary focus [12].

Since 1970 the ANUIES (National Association of Universities and Institutions of Higher Education) postulated Interdisciplinarity as an alternative to renew the fields of knowledge, to build a new dialogue between disciplines to efficiently solve research problems and to articulate a constructivist perspective to knowledge and school learning. This Interdisciplinarity required a new organizational structure, but above all a deep revision of the division of academic work; although modernization led to the opening of new academic offerings, interdisciplinarity was mentioned in paper and in the objectives to be achieved throughout the higher education system, its results in these years were meager.

Decisions in general in the environmental sector of Mexico during the 20th century were taken unilaterally by governments (bureaucrats with traditionalist formations of lawyers, administrators, doctors, accountants, biologists, etc.), democratization in the environmental sector changes with the modernization of higher education where the academic sector begins to play with the creation of professions related to the environmental sector and the modification of traditional careers approaches.

There are currently 1200 academic programs nationwide on environmental issues although most of them are based on natural and exact sciences, with a reductionist vision in the search for solutions.

In the National Polytechnic Institute, the second largest and oldest public university in Mexico, the following strategy was presented: creation of new careers related to the environmental sector, updating of the programs of traditional careers including subjects related to environmental pollution, ecology, and environment. It also created Research Centers that will address the environmental issue in an interdisciplinary manner and create a postgraduate division that will encourage work in research networks, thus bringing together researchers from different schools to work jointly on postgraduate research and training projects. Within this program is the Environment Network and the Economic Development Network, which in an interdisciplinary way works for innovation in the postgraduate course [13].

Currently the National Polytechnic Institute has the following academic offers related to the environmental sector and the discipline, multidisciplinary and interdisciplinary [14]:
At the technical level: we have two clearly environmental careers such as: Technician in Ecology, Technician in Diagnosis and Environmental Improvement, and in 9 we have incorporated environmental matters such as: industrial safety and environmental impact, environmental impact in public and private sector projects, sustainability of plastics, control and elimination of hazardous waste, control and disposal of chemical waste, solution to an environmental problem, effects of contaminants on health, control and elimination of hazardous waste, sustainable development.

At the Bachelor's level: we have two streams of environmental engineering: Engineering in Environmental Systems and Environmental Engineering. And among the 21 types of engineering and 10 bachelor's degrees there are about 58 subjects, either compulsory or optional with environmental training: Sustainable development, environmental geophysics, sustainable development, climatology and climate change, environmental management, environmental engineering, cleaner production, natural resources and sustainable development, alternative energies, environmental engineering, environmental administration and management, sustainable social housing, landscape architecture, environment and city architecture, sustainable buildings and recycling of buildings, management and management of green areas, environmental assessment and sustainable development, sanitary engineering and environmental, water quality and contamination of water bodies, design construction and monitoring of sanitary landfills, drainage and landscape, integral management of watersheds, environmental geology and geological risk, basin analysis, characterization and remediation of contaminated sites, legal foundations of geoenvironmental management, assessment of aquifers, environment, environmental management and clean technologies, recycling technology, energy and environmental chemistry, risk planning and environmental impact, treatment and remediation of waste from the food industry, environmental protection, automotive environmental engineering, technology environmental clinic, ecology, environmental audit, tourism and the environment, environmental management system for tourism, management of sustainable tourism, industrial safety and environmental systems, environmental planning and management, natural and cultural diversity of Mexico, environmental planning and evaluation in Mexico , innovation and sustainable initiatives.

And at the graduate level we have multidisciplinary and interdisciplinary areas: which includes four doctorates in environmental science. Doctorate in Sciences in Agroecological Management of plagues and diseases, Doctorate in Sciences in Conservation of the Landscape Patrimony, Doctorate in Sciences in Fish and Aquaculture Bioeconomy, Doctorate in Marine Sciences.

10 master's degrees: Master of Science in Sustainable Agricultural Production, Master of Science in Environmental and Sustainability Studies, Master of Environmental Management and Audits, Master of Engineering in Cleaner Production, Master of Marine Resource Management, Master of Business Administration for Sustainability, Master of Science in Environmental Management, Master's Degree in Geosciences and Natural Resources Administration, Master's Degree in Project Management for Solidarity Development (With Professional Orientation), Master of Science in Conservation and Exploitation of Natural Resources.

1 specialty: Specialty in Management of Coastal Environments.

2 courses of specific purpose (the courses offered to the general public): The environmental complexity of the city, Epistemology of environmental complexity in urban studies.

Besides the 9 doctorates and 24 disciplinary, multidisciplinary and interdisciplinary master's degrees we have offered 33 optional subjects Environmental biotechnology and sustainable resource management, health ecology, Mexico's biodiversity and sustainable development, environmental biotechnology, industry and its impact on the environment , social architecture and sustainability, safe and sustainable housing, society and climate, environmental physics in buildings, sustainable architecture: current scenarios, selected topics of environmental systems, energy and sustainability, environmental impact of energy systems, competitiveness and sustainability in companies and organizations, environmental economics, experimental methods in environmental chemical engineering, environmental engineering, natural environments, ecosystems and tourism, environmental management for tourism, environment and tourism, formulation and social, economic and environmental evaluation of projects, development, sustainable development and innovation, educational management and sustainable development, development and sustainability, rural and sustainable projects, sustainable innovation, product input and environmental accounts, sustainable regional development, physical oceanography, environmental modeling.

The above mentioned offers that are prevailing in the National Polytechnic Institute even now in 2017, still there is a strong tendency to discipline in the area of higher education and attention to the first stage of environmental problems: such as pollution, At the graduate level the multidisciplinary and interdisciplinary words are observed for a holistic approach. The "delay" or lag in the educational sector, especially at the higher education system in Mexico, is due to the country's development demanded the environmental sector and its direct relationship with the options based on the priorities (or long or short term visions, beliefs, customs, preparation, ideologies, political parties, etc.) of the votes (we have not yet developed our democracy for the important decisions fall on the independent society of the colors of which the sexennial transgressors). The rise and subsequent abandonment of higher education over 50 years brought the lack of national human resources that can make decisions on the direction of the environmental sector and the country in general. Innovative modernizing proposals based on the interdisciplinary work that was proposed in the decade of the 70's provided an advance, but it was not enough since there are pending works in the interdisciplinary area of the academy.

Currently, work is being carried out at the graduate level to include Interdisciplinarity in scientific research, master and doctoral programs. In the present work we highlight the effort that has been taking place since the 80's which brought together the environmental sector and interdisciplinary work.

3.4 Sustainability from the Interdiscipline in Mexico

Currently Mexico has several educational centers that have been born from the idea of Interdiscipline and Multidiscipline, in which many of them were created by institutions of higher education such as the National Polytechnic Institute (IPN) and the National Autonomous University of Mexico (UNAM), in the eighties. Regional Center for Multidisciplinary Research (CRIM) by UNAM in 1983, which aimed to create a space for collaboration between different disciplines, including social, humanistic and scientific, in the approach of objects and research topics directly linked to the problem of the social reality of our country is an example for this [15].

On the other hand, the IPN was chosen for the creation of a master program that would responsible for the training of human resources capable of addressing the problems in Mexico and the region as a result of a call made by the United Nations Environment Program (UNEP) in 1982. In subsequent meetings steered in the cities of Morelia and Morelos, the design of Latin American academic space for the formation of high-level human resources was discussed which would be, responsible for forming a scientific and technological structure and proposing appropriate solutions for the environmental and social conditions of the region and at the national level. That was how the Master's Degree in Environment and Integrated Development (MADI) was born. In August 1984 academic and scientific cooperation between the IPN and the University of Paris III, Sorbonne-Nouvelle de France, began to somehow complement the efforts made with the MADI, by proposing a doctorate in continuity with the proposal to study for two years in the IPN and conclude at the University of Paris III. Derived from the same, the MADI project is changed as the Interdisciplinary Project on Environment and Integrated Development (PIMADI). It is important to note that although there was little background in the approach to environmental problems from academia in Latin America at that time., the program, which was the result of an original idea, was internationally accepted as the environment should be considered as the interrelation of society and nature, so it was considered the training of specialists who would conduct studies through research of an interdisciplinary nature, The highly qualified academic staff in various areas of knowledge, such as earth sciences, social and economic sciences, physical sciences math, biological sciences and engineering were require to participate among others to make this interdisciplinary study. Under the international context of the United Nations Conference on Environment and Development on 1992, in Rio de Janeiro, Brazil, which resulted in the publication of the "Agenda 21", the IPN faced changes., it demanded the constant advancement of knowledge that preserves and increases its results with better criteria and standards of generalizations, as well as it sought to direct its efforts to satisfy the demand for training and research spaces in the field of environment and development., In correspondence with this, their projects of greater importance for the benefit of society was expanded with the sectoral programs of education, environment, science and technology, energy and transport in accordance with the institutional development program 1995 – 2000. The H. Consultive General Council of the IPN, in its Tenth Ordinary Session, held on October 31, 1996, authorized the agreement establishing the Interdisciplinary Center for Research and Studies on Environment and Development (CIIEMAD), having as a platform, the patrimony until then attributed to PIMADI.

This agreement by which the CIIEMAD was established, was published in the Polytechnic Gazette, in number 382, year XXXII, volume 1, on December 15, 1996, its first article to the letter says: "... so that Through its educational processes and the implementation of interdisciplinary scientific and technological research projects, develop and promote harmony between economic growth and sustainable development for the benefit of our country" [16].

The CIIEMAD can be considered as the space offered by the IPN in terms of environment and development, under an innovative interdisciplinary work model that has been operating for 35 years. Currently the CIIEMAD has 34 teachers, 26 doctors and 8 masters in science, with disciplinary training at the undergraduate level (chemical engineering, civil engineering, biology, sociology, anthropology, geology, economics) and with disciplinary and multi-interdisciplinary training at the Master's degree and doctorate (master's degree in environmental engineering, doctorate in chemistry, doctorate in Latin American studies, doctorate in public policies, doctorate in urbanism, etc.) with national and international studies. There are two programmes:

Master of Science in Environmental and Sustainability Studies (incorporated into the national graduate programs of quality of CONACYT, previously was the Master's Degree in Environment and Integrated Development).

Doctorate in Sciences in Conservation of Landscape Heritage (This program is found in the national graduate programs of quality of CONACYT, and is the result of the work of the research networks that formed the IPN, to promote interdisciplinary work in the postgraduate program, CIIEMAD is a node of this doctorate).

There were two more programs, which were declared in recess for their limited possibilities to comply with the guidelines of the CONACYT programs:

Doctorate in Environment and Integrated Development and the Master in Environmental Management and Audits, which operated online in agreement with the Ibero-American University Foundation (FUNIBER).

The CIIEMAD has tried to maintain the offer of a globalizing knowledge more applicable to the solution of environmental problems with a perspective of sustainable development through an inter and transdisciplinary approach.

Its main lines of research are divided into three departments (Table 3.1). Under this scheme of departmental organization some of the projects that have been developed are shown in Table 3.2. The offer of elective courses in CIIEMAD are shown in Table 3.3.

In its enrollment the CIIEMAD can locate students of diverse disciplines interested in environmental aspects and finding different visions to approach the same object of study; among the latest thesis topics that have been handled in the Master of Science in Environmental Studies and Sustainability, the current Master's program of CIIEMAD, are (Table 3.4 & 3.5):

The behavior of the enrollment in this program since 2010, when it was updated, is shown in Table 3.6.

Among the main problems faced by the CIIEMAD, in its day-to-day activities, are the disciplinary limitations from design and delivery of a subject, the composing of work teams for the construction of a thesis and the frequent loss of the holistic approach to environmental problems. It's worth mentioning that new hires lack of collective memory of the spirit of creation of CIIEMAD, were they only seem to perceive CIIEMAD and IPN as a source of income.

Interdisciplinary work is sometimes complicated by the policies dictated by the National Council of Science and Technology (CONACYT) at the national level on the productivity of teachers-researchers and distinctions to graduate programs. It has created a work dynamic that increasingly distances the teacher from teaching and the researcher brings it closer (restricts) towards lines that CONACYT has established, considering that for the evaluation both the researcher and the programs have a limited margin to expand his investigations for the risk of leaving outside the lines of investigation declared, since the “non-disciplinary" is perceived as something residual, outside the “normal" science. Interdisciplinarity is observed as something not normal, unstable and without coherence, so the challenges faced by Interdiscipline for its development in Mexico can said to be structural, cognitive and normative. CONACYT is the public institution in charge of dictating the policy of science and technology in the country, currently has, among others, two recognitions, one to nationally recognized researchers which he calls “national system of researchers”, which grants the distinction through an economic recognition to the teacher-researchers, mainly for their productivity of indexed international articles; the other recognition is the one that grants to the programs that have a teaching staff of SNI'S, called “national program of postgraduate of quality" among the requirements to be part of this distinction are the academic productivity of teacher-student, enrollment, terminal efficiency etc., so both teachers and universities seek to obtain such recognition and are working to achieve their income, to meet the requirements.

3.5 Conclusions

Interdiscipline in the environmental sector of Mexico is in the process of development. As we have observed throughout the work, the demand for interdisciplinary professionals has been and is growing. The academy within its formative role, depending on a government, has made its efforts which have fallen far short of what is required, somewhat as we analyze for issues unrelated to them (political context, budget etc.) and other internal (the rigidity of teachers facing change). The international context has marked the tendencies of the type of personnel required for the new challenges demanded by institutions to face current situations. However, Mexico continues with educational policies and the science and technology distant itself from promoting the formation of resources and interdisciplinary projects, With these measures the academy participates somewhat distant and perhaps challenges to move from the discipline to the Interdiscipline and a more to the Transdiscipline, by the repercussions that this can bring as to face the policies of the system. The environmental sector will continue to advance in Mexico with or without interdisciplinary personnel, as it has been doing, the truth is that we will continue to lose resources day by day as in the beginning of the history of the country, independent on paper and dependent in practice.

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Table 3.1: Environmental Law (Source: [17])

Biosciences and Engineering	**Territory and Environment**	**Society and Environmental Policy**
Health and Environment	Integrated management of biotic resources and Conservation Biology	Environmental Law
Study of the mechanisms of action of the hypoglycemic effect of medicinal plants used in the treatment of diabetes	Social Anthropology, Fishermen and Riparian Fishing	Environmental Management
The protein crown as a modulator of the inflammatory response to nanomaterials	Fishing Policies in Mexico and Latin America	Fisheries legislation
Evaluation of the adverse effects induced by nanomaterials	Coastal Development and Environment	Public Policies and the Environment
Synthesis of Nanostructures, Applications and Environmental Implications	Territorial Transformations and “Arrangement" of the Territory	Socio-urban processes and the environment
Simulation of Environmental Capillary Processes	Development and Sociourbano Metropolitan Environment and Historical Centers	Territory, tourism and environment
Nanoproducts, Nano-waste and Urban Solid Waste	Regional Socio-Urban Studies	Metropolitan urban development
Pollution and atmospheric monitoring	Development, Environment and Sustainability	Research Methodology

Table 3.1: Environmental Law (continued)

Biosciences and Engineering	Territory and Environment	Society and Environmental Policy
Environmental Toxicology	The complexity in sustainable issues of socio-environmental problems	Environmental Education
Pollutant Evaluation in Environmental samples	Territory, city, capital and spaces in transformation	Educational Innovation
Ecophysiology and Bioenergetics of key species in freshwater systems	Territorial and Environmental Transformations	Sustainable Universities
Water quality, geochemistry, accumulation of toxic metals in water, sediments in soil and fish (rivers, estuaries and coasts)	Alternative Turism	Governance
Identification of Tsunami deposits (Present and paleo deposits)	Urban Transportation, Environmental Audit	Public Policy
Degradation and restoration of Mangroves	Planning and Public Policy (environmental, rural and fiscal)	Public and environmental management
Paleoclimatology studies	Environmental and Ecological Economics (valuation and indicators)	Strategic environmental planning in Mexico

Table 3.1: Environmental Law (continued)

Biosciences and Engineering	**Territory and Environment**	**Society and Environmental Policy**
Biological Treatment of Wastewater	Sustainable Use of Natural Resources in agrarian centers	Territorial ecological ordering
Geo-environmental Studies and Geostatistics	Food Security and Local Development	Integral Coastal Management
Applied Environmental Geomatics	Hydrometeorological risks	Coastal - Marina Pollution
Synthesis, characterization and evaluation of catalysts for obtaining low sulfur fuels	Geological characterization of areas susceptible to landslides	Public Policy
Biosciences Limnology Characterization of inland waters	Identification of landslide deposits	Housing Policy and Environment
Pollution and environmental deterioration by metals, bioavailability in Aquatic Systems Geochemical cycles	Natural Resources (soil, water, minerals)	Territorial Transformations
Environmental analysis in the sediment water interface and the animal soil plant relationship	Regional Urban Development	Housing, Environment and Quality of Life
Hydrometeorological phenomena	Sustainable Architecture	Territorial Planning
Impact of Marine Resources	Analysis of normative bodies from their implications in society, the environment, climate change, and sustainable development	Management of natural resources and Sustainable Rural Development

Table 3.1: Environmental Law (continued)

Biosciences and Engineering	**Territory and Environment**	**Society and Environmental Policy**
Hydrometeorological phenomena	Sustainable Architecture	Territorial Planning
Impact of Climate Change in Mexico	Environmental Regulation	Agroecology
Pollution and monitoring of contaminated sites	Territorial Reservations	Rural Development Policies
Prevention and Control of Pollution (Solid Waste, Soil Remediation)	Environmental diagnosis	Rural History and Culture
Residual and synthetic natural fibers for the automated conformation of eco-friendly technical textiles with the environment for their application in ballistics and civil engineering	Environmental Evolution	Participatory methodologies
Econcomposites generated by unconventional processes and the dynamics associated with these processes	Restoration of degraded soils	Public Policy and Environment
Controlled functionalization of fibrous materials and regulated porosity with applications mainly agribusiness, ballistics, electronics, civil engineering and in the production of low environmental impact fuels	Environmental Impact in Development Works	Science Methodology
		Work Environment

Table 3.2: Projects Developed in CIIEMAD (source: [17])

Biosciences and Engineering	**Territory and Environment**	**Society and Environmental Policy**
Heavy metals in the muscular and liver tissue of sharks of Baja California Sur	Study of the dynamics of use and appropriation of resources in Chiloé Island, Chile	Study on successful Public Policies in the world of sustainable development
Bioaccumulation of heavy metals (mercury and cadmium) and selenium in the stingrays of the western coast of Baja California Sur	Biological-fishing study shrimp species of coastal lagoon systems of Yucatan	Social participation to solve environmental problems: governance and climate change
Study of the mechanisms of action of the hypoglycemic effect of the total extract and subfractions of Ibervillea sonorae in a hyperglycemic rat model	Transformations and uses of space in the coast of Colima	Environmental Prospective, a contribution for the territorial ecological ordering of the Municipality of Tlaxco, Tlaxcala
Activation of the CFTR channel as a possible mechanism of action in Chronic Kidney Disease associated with fluoride exposure	Socio-urban environmental challenges in México City; case Delegation Cuauhtémoc	Plan of Action for the sustainable development of CIIEMAD

Table 3.2: Projects Developed in CIIEMAD (continued)

Biosciences and Engineering	Territory and Environment	Society and Environmental Policy
Synthesis of semiconductor nanostructures and the inventory of their nano-waste involved	Impact of the informal sector of the economy on the architectural urban cultural heritage of the Historic Center of Mexico City	Diagnosis of institutional capacities for the environmental management of the states in Mexico
Analysis of nano-waste generated during the obtaining of oxide-metallic nanostructures	The socio-environmental problems and the territory in Mexico	Baseline diagnosis of urban solid waste management for the formulation of an integral management plan for urban waste in the state of Quintana Roo, Mexico
Sustainability of the productive processes in the synthesis of Nanostructured Materials	The socio-urban environmental spaces and the territorial organization in the sustainability?	Design of methodological instruments and creation of a data bank for the construction of the environmental history of the ejido San José de las palmas, municipality. Union of San Antonio, Jalisco

Table 3.2: Projects Developed in CIIEMAD (continued)

Biosciences and Engineering	**Territory and Environment**	**Society and Environmental Policy**
Mitigation strategies for greenhouse gases generated by urban solid waste in Mexico	Definition of an environmental frame of reference and diagnosis of compliance in the territorial organization of mobility and urban transport for a delegation of the federal district	Socio-environmental modifications in rural communities in the city of Mexico. Case study: Ocuilan, State of Mexico
Towards green Nano science: natural resources, production processes, nanomaterial, nanoproducts and nanor-residues	Criteria for articulation of public transport modes	Diagnosis of affectations to the hydric resource caused by the open-air dump in Zinápecuaro, Mich.
Neurotoxic effect of lead in the central nervous system. On the metabolism of dopamine and tetrahydrobiopterin	Perspectives of urban environmental policies for the sustainability of the city: Mexico City	
Urban atmospheric particles. Sources, composition and toxicity	Design of strategic socio-environmental lines for the 'state program for the prevention of integral waste management (PEPGIR) in Quintana Roo, Mexico	

Table 3.2: Projects Developed in CIIEMAD (continued)

Biosciences and Engineering	Territory and Environment	Society and Environmental Policy
Biotechnological alternatives for the processing and reuse of fruit and vegetable waste from the northern area of Mexico City	Methodological analysis of environmental audit practices with participation of social actors	
Evaluation of the geomobility of heavy metals in the surface sediments of the mining and metallurgical district of Santa Rosalia, Baja California Sur	Application of environmental economic evaluation indicators for social producers	
Establishment of a Management Program for the coastal zone of the southern region of the Gulf of California	Indicators of analysis of economic evaluation with environmental criteria for agrarian nuclei	
Isotopic enrichment and trophic levels of the prey and habitats exploited by the California sea lion off Magdalena Bay, Mexico	Methodology of analysis of sustainable use of lands of common use in the state of Veracruz	
Effect of inorganic fertilizers on the degradation of triazine herbicides	Indicators of environmental degradation in the Zahuapan river basin, Tlaxcala state	
Bioprocesses for the degradation of synthetic azo-anthraquinone and trizinic dyes	Analysis of the environmental policy in Mexico and its current instruments enforced in 2011	

Table 3.2: Projects Developed in CIIEMAD (continued)

Biosciences and Engineering	Territory and Environment	Society and Environmental Policy
Bioprocesses to mineralize the herbicides derived from urea, diuron and linuron	Evaluation of the Methodologies of Federal Public Policies: Strengths and Weaknesses	
Presence of genes for the catabolism of herbicides in microbial consortia and their relation to the operational stability of biobarriers utilizadas para su degradación	Diagnosis of the indigenous ecotourism policy in Mexico 2000-2006	
Location and analysis of critical areas due to the use of pesticides in Mexico. Case study: Tecolutla River, Tecolutla Sub-basin in Veracruz	Health diagnosis of the Villa Montemorelos and El Arenal communities of Durango, Mexico	
Development of a bio-enrichment process of a biobarrera for degradation of the commercial herbicide Tordón (2,4-D + Picloram)	Development of a GIS of sites contaminated by agrochemicals in the municipalities of Tecolutla, Gutiérrez Zamora and Papantla in Veracruz, Mexico	
Location and analysis of critical areas for the use of pesticides in Mexico (Municipalities of Gutiérrez Zamora and Papantla in Veracruz)	Health effects of the human populations of the San Pedro Mezquital Basin as a result of the management of its wastewater	

Table 3.2: Projects Developed in CIIEMAD (continued)

Biosciences and Engineering	**Territory and Environment**	**Society and Environmental Policy**
Isolation of microorganisms with the ability to degrade formulations of herbicides containing nicosulfuron	Environmental risk factors of sanitary landfills in the Federal District and the conurbated area and their relation to health, quality of life and precarious work of segregators	
Hydro geochemical Rector Study of the Wells in the Aquifers of the Metropolitan Zone, Puebla (First Stage)	Strategic planning of the productive chains of smaller pelagic fish and clam Catarina, for its sustainable use	
Network of Monitoring Stations for the Preservation, Conservation and Improvement of Water Quality in the Alto Atoyac Basin Corresponding to the State of Puebla	Characterization of the geological hazards present in Motozintla, Chiapas	
Update of the 2016 Tariff Agreement, Water of Puebla		
Responsible Management of Wetlands and Micro-basins and in turn Maintaining Ecological Balance in the City of Puebla		
Biofilter Demonstration Project at the Valsequillo Dam		

Table 3.2: Projects Developed in CIIEMAD (continued)

Biosciences and Engineering	Territory and Environment	Society and Environmental Policy
Evaluation of the toxicity of metals and concentration patterns of Habitat (Water and Sediment) and prey of the Sea Lion of Magdalena Bay, Baja California		
Statistical analysis of extreme hydrometeorological events in the south and southeast of Mexico		
Analysis and dissemination of the legislation applicable to fishing activity in the state of Quintana Roo		
Climate change and the occurrence of extreme weather events in Mexico during the 20th century		
Scenarios and Vulnerability to Climate Change of Fishing Activity in the Gulf of California		

Table 3.3: Elective Courses in CIIEMAD (source: [17])

Biosciences and Engineering	**Territory and Environment**	**Society and Environmental Policy**
Biofuels and Environment	History of the Environment and Development in Mexico (1950 - 2000)	Patents in Environment and Development
Integrated Management of Urban Solid Waste	Ecological Planning of the Territory	Preparation and Presentation of Research Products
Environmental Toxicology	Territory, Environment and Sustainable Development	Statistics
Comprehensive management of hazardous waste	Environmental impact assessment	Introduction to Qualitative Methods of Research Applied to Environmental Analysis
Clinical principles of exposure to environmental toxins	Environmental and Ecological Economics	Fundamentals of Geographic Information Systems for Environmental Studies
Introduction to Environmental Chemistry	Methodological Tools for Evaluation of Programs and Public Policies	The Art of Scientific Writing
Selected topics of environmental epidemiology	Introduction to Public Policies and their Evaluation	Advanced Statistics

Table 3.3: Elective Courses in CIIEMAD (continued)

Biosciences and Engineering	Territory and Environment	Society and Environmental Policy
Risks due to natural phenomena	Governance	
	Transdisciplinary research for sustainability	
Geo-environmental methods	Environmental Education	
	The paradigm of integral ecology as a path for landscape management	
	Environmental Law	
	Socio-environmental political economy	
	Environmental policy and its instruments	
	Strategic Environmental Planning in Mexico	
	Organizations and Sustainable Institutions	

Table 3.4: Master's Thesis in Science in Environmental Studies and Sustainability Studies (source: [17])

Biosciences and Engineering	**Territory and Environment**	**Society and Environmental Policy.**
Evaluation of tropospheric aerosols of the AMCM by means of GOES satellite images.	Analysis of the Localized Agro-Food System of Coffee in the Municipality of Naupan, Puebla.	The environmental knowledge of the visitor of the protected natural areas: Case study National Park "Cumbres del Ajusco".
Electrochemical treatment of wastewater derived from the leaching of natural rubber latex products.	Social vulnerability and adaptation of the Apatlaco River basin to the effects of climate change on water availability.	From citizen participation in Environmental Policies to sustainability. A process under construction.
Waste management plans for high-volume generators: The case of the Abastos plant in Mexico City.	Impact of architectural reuse in the socio-urban environment. Case study: Two sets of homes located in the historic center of Mexico City.	Guidelines for ecological ordering in archaeological zones: Case study Cuicuilco, Mexico.
Pharmacological evaluation of the hypoglycaemic effect of "Ibervillea sonorae"	Community Cultural Tourism in the safeguard of the chinampero heritage in San Gregorio Atlapulco, Xochimilco, DF.	Towards cross-effects in poverty and environment? Analysis of public policies. The case of Lacanja, Chiapas.

Table 3.4: Master's Thesis in Science in Environmental Studies and Sustainability Studies (continued)

Biosciences and Engineering	Territory and Environment	Society and Environmental Policy.
Optimization of the composting process produced from the organic fraction of urban solid waste generated in Mexico City.	Comparative study between conventional apiculture production and fair trade organic beekeeping production by small producers of the State of Mexico.	Analysis of intergovernmental cooperation in the management of the water resources of Lake Tlahuac-Xico. An approach from the public policy approach.
Development of computational tools for the management of environmental databases: Case study of urban agricultural ecosystems in Mexico City.	Use of remote sensing systems and geographic information in the participatory diagnosis of the rural coffee territory of the municipality of Xicotepec, Puebla.	Conflicts, denomination of Magical Town and the paper amate in Pahuatlan de Valle, Puebla.
Estimation of methane emissions from the Bordo Poniente Landfill through satellite images.		Diagnosis of the physical dimension of the Technological University of Tula Tepeji as a basis for an environmental education program.

Table 3.4: Master's Thesis in Science in Environmental Studies and Sustainability Studies (continued)

Biosciences and Engineering	Territory and Environment	Society and Environmental Policy.
Study of the valuation of organic waste contained in the urban solid waste generated in the Federal District.		Social perception of the environment and urban growth in San Cristóbal de las Casas Chiapas. Study among young University students.
Program of prevention and integral management of urban solid waste for the municipality of Almoloya de Juárez State of Mexico.		The theory of planned behavior and the dimensions of the green school in basic education. Case study: Juan Ramón Jiménez Elementary School and the Luis Donaldo Colosio Pedagogical Center.
Calculation program to estimate the amount of leachates generated in sanitary landfills.		Proposal of a public policy instrument to regulate the sustainable production and consumption of green products: Eco-labeling in Mexico.
Evaluation of metals and non-metals in the fine fraction of atmospheric particles in the Metropolitan Area of the Toluca Valley.		Elements for a non-formal education program based on Human needs.

Table 3.4: Master's Thesis in Science in Environmental Studies and Sustainability Studies (continued)

Biosciences and Engineering	**Territory and Environment**	**Society and Environmental Policy.**
Experimental technical design of composites from the recycling of PET / EN and its possible application in construction.		Proposal of energy indicators of sustainable development for renewable sources in Mexico.
Evaluation of the wheat straw residue of the Pleurotus djamor culture as a substrate for anaerobic digestion.		Public-Private Partnerships as a public policy strategy for sustainable development. Case study: The bicycle as an alternative transport for the Adolfo López Mateos and Ticoman units of the IPN, Mexico City.
Study of the Development of the Species Ricinus communis, cultivated in mining waste under greenhouse conditions.		Analysis of the socio-environmental impact by the denomination Magical Towns in Pahuatlan del Valle, Puebla.
Valorization of natural products in Teotitlán del Valle Oaxaca, with sustainable processes. Case Lana.		Evaluation of the Design of the Municipal Climate Action Plan (PACMUN) as an initiative for the development of a public policy.

Table 3.4: Master's Thesis in Science in Environmental Studies and Sustainability Studies (continued)

Biosciences and Engineering	Territory and Environment	Society and Environmental Policy.
Mitigation actions of greenhouse gases from the management of urban solid waste in urban centers of more than 50 thousand inhabitants. Case study: Acapulco de Juárez, Guerrero, Mexico.		The sense of the place and its relation with the attitudes and pro-environmental habits in students. The case of the Gánale al CO_2 program.
Effect of water dispersion of arsenic, cadmium and lead on the quality of the sediments and surface water of the San Miguel micro-watershed, Zimapan.		The notion of the environment of girls and boys of 5th and 6th grade of primary school in Mexico City and the City of Oaxaca.
Identification and use of nano-waste generated during the synthesis of nanomaterials.		
Analysis of the environmental behavior of the most commonly used herbicides in the Rio Tecolutla sub-basin, Veracruz. Case study: Municipalities of Tecolutla and Gutiérrez Zamora.		

Table 3.4: Master's Thesis in Science in Environmental Studies and Sustainability Studies (continued)

Biosciences and Engineering	Territory and Environment	Society and Environmental Policy.
Analysis of the carbon footprint and nutrient content of the nixtamal mass produced in mills located in a ZMVM under the GTG model.		
Microbiological characterization of leachate produced by the Compost plant of Bordo Poniente.		
Determination of herbicides in environmental matrices: soil and water, in Papantla, Veracruz.		
Evaluation of the digestate generated by the anaerobic digestion of the organic fraction of urban solid waste in Mexico City.		

Table 3.5: Master's Thesis in Science in Environmental and Sustainability Studies Conducted by 2 Areas (source: [17])

Biosciences and Engineering + Territory and Environment	**Territory and Environment + Society and Environmental Policy**	**Society and Environmental Policy + Biosciences and Engineering**
	Analysis of the impact of Urban Cultural Tourism in the Historic Center, World Heritage Site of the City of Puebla de Zaragoza, Mexico.	Ergonomic study of agricultural practices during the growth and transplantation of coffee plants.
	Evaluation of the urban public policies of Tecámac de Felipe Villanueva, State of Mexico for the achievement of a sustainable urban management.	The relationship between governance and sustainability in the fishing production cooperative society La Plan, La Encrucijada Biosphere Reserve, Chiapas, Mexico.
	Analysis of consistency evaluations and results of federal programs subject to operating rules, case study: PAL 2007-2011 clean water program.	Social advertising campaign to encourage the separation at the source of recyclable solid waste for the inhabitants of the Federal District.

Table 3.5: Master's Thesis in Science in Environmental and Sustainability Studies Conducted by 2 Areas (continued)

Biosciences and Engineering + Territory and Environment	**Territory and Environment + Society and Environmental Policy**	**Society and Environmental Policy + Biosciences and Engineering**
	Family farming to sustainable use of orchids in Xicotepec de Juá rez, Puebla.	A rehabilitation strategy for abandoned tailings dams in the municipality of Zimapán, Hidalgo.
	Perception on the green areas of the residents of the Hipódromo neighborhood, Delegación Cuauhtéémoc, Mexico City.	Socio-ecological diagnosis of the Arroyo Peña Gorda watershed, Gustavo A. Madero DF. Elements for holistic management.
		Use of herbicides and their spatial distribution in the Rio Tecolutla sub-account (municipalities: Tecolutla, Gutiérrez Zamora and Papantla).
		Identification of agrochemical contaminants and their relationship with the socio-economic activities of the communities surrounding the Laguna de Santiaguillo watershed, Durango.
		Minamata Agreement and regulation of mercury in Mexico.

Table 3.6: Enrollment in CIIEMAD (source: [17])

Class	**Students**	**Graduated**	**Drop outs**	**Current**	**Graduation %**
I A10 January - July, 2010	5	3	2		60
II B10 August - December 2010	4	3	1		75
III B11 August - December 2011	13	9	4		70
IV B12 August - December 2012	9	7	2		78
V B13 August - December 2013	20	17	3		85
VI B14 August - December 2014	18	14	4		78
VII B15 August - December 2015	11	6	1	4	55
VIII B16 August - December 2016	17			17	Graduation in 2018
IX B17 August - December 2017	6		2	4	Graduation in 2019

CHAPTER 6

Research *In-between*: The Constitutive Role of Cultural Differences in Transdisciplinarity

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Transdisciplinary research can be considered an integrative practice that is grounded in difference. It emerges as in-between space established among societal domains, different ways of knowing, acting and being, and constitutes a new topos in the landscape of societal institutions. We argue that it is through difference that transdisciplinary research spaces are created and elaborate on the characteristics of these in-between spaces. We provide insights into theoretical considerations of the constitution of transdisciplinary research spaces and show how cultural differences, determined by existing power relations and hegemonies, can be brought into fruition. Our aim is to contribute to theoretical considerations of a concept of research that is not reduced to academic research only but considered a cultural practice of people at stake to better understand and transform situations or phenomena of shared interest.

Keywords*:* Research topography, Third Space, integration, differentiation, responsitivity, power relations, transformative research.

4.1 Introduction

In academic discourses on fragmentation and divergence, C. P. Snow's *Rede Lecture* on *The Two Cultures*, held in 1959, has marked a milestone. Snow criticises the inability of scientists and humanists to communicate with each other "on the plane of their major intellectual concerns", and points to the "gulf of mutual incomprehension" [1] (4). For him, fragmentation and divergence have serious consequences: "It is leading us to interpret the past wrongly, to misjudge the present, and to deny our hopes for the future. It is making it difficult or impossible for us to take good action." [1] (60). Since then, the landscape of knowledge has changed significantly.

The hypothesis of 'two cultures' is out-dated and both fragmentation and attempts to overcome the divides have intensified significantly. The number of specialized fields of knowledge is constantly increasing, but at the same time diverse forms of collaborative, boundary-crossing research practices have developed. Interdisciplinary fields of research, institutions and training programs have evolved in diverse thematic fields [2], [3], and transdisciplinary research has been conceptualized, practiced and discussed for nearly five decades (for an overview on different discourse strands see: Osborn [4], Klein [5]). However, interdisciplinary research is still not mainstream in the academic system [6], [7] and remains an intellectual, cognitive, communicative, and institutional challenge, particularly in the context of practicing broad interdisciplinarity [8] and working in traditional academic institutions [9]. Transdisciplinarity is hardly consolidated and remains a marginal phenomenon so far, and, above all, it is highly contested. This is not surprising for a concept of research that aims at overcoming divides, not only between academic knowledge fields but also between different cultural spheres of societies [10]. It tackles core pillars of modern science [11], [12], [13] and, as a consequence, the privileged position of the scientific method, by undermining separation [14]. However, the call for a mode of research that does not only cross boundaries of disciplines, but also links knowledge production to the transformation of situations, and, as a consequence, entangles epistemic and transformative objectives, is not new. It is as old as the separation of scientific institutions from the 'remaining rest' [14] and has been put forward by many influential authors who have addressed the challenge from different perspectives over the last decades (e.g., Freire [15], Piaget [16], Hall [17], De Certeau [18], Haraway [19], Guattari [20], Rorty 2002 [21], Nicolescu [13]). Important contributions to research embedded in practice and oriented towards societal transformation have been made by Action Research and Participatory Action Research in various fields in different world regions [22]. Ultimately, the presence of a large number of pressing social and environmental challenges of global dimension [23] proves that there is a need for new ways of dealing with them in order to move towards sustainable, healthy, equitable and peaceful futures. When looking at attempts to fight e.g. climate change, biodiversity loss, warfare and the increase of racist behaviour, the current fragmentation and divergence in societal organization turns out to make it "difficult or impossible for us to take good action" – as Snow stated. Fragmentation and divergence are, of course, not only a result of a search of efficiency. They are a product of contentions concerning dominant societal roles and positions and reflect cultural hegemonies. Thus, there is a constant need to recall questions that have already been posed years ago in the field of postcolonial studies and with Gayatri Spivak we ask [24]: Who can speak out loudly? Whose voice is heard, whose knowledge accepted? And, as a corollary, where are places for people to speak out, to be heard and to exchange *knowledges* and experiences with the ultimate aim to change ways of appropriation and belonging to create sustainable conditions?

In this chapter we elaborate on the constitution of spaces that are created between established institutions, communities and cultures. We emphasize the potential of actively dealing with differences. In order to make use of differences for the constitution of such in-between spaces, we draw on a broader concept of research that acknowledges the complementarity of academic research practices and other ways of knowing, acting and being in responding to a particular situation or phenomenon of concern. We argue that multiple ways of appropriation and belonging can lead to better grasp the complexity of a situation or phenomenon to gain a more profound understanding on how individual and collective transformation can be achieved, and to actually transform the situation through joint research. In a first step we will elaborate more profoundly on the argument for a broader concept of research. We then look at transdisciplinarity through the lens of culturality that brings about the need to face and approach cultural hegemonies between these different ways of knowing, acting and being. Subsequently, we elaborate on the theoretical framework of in-between spaces that is informed by to main concepts: the responsive logic of Bernhard Waldenfels [25] and Homi Bhabha's concept of Third Space [26], [27]. Both concepts rely on a relational understanding of space and imply the possibility to deal with power relations.

This work is based on experiences in experimenting and practicing transdisciplinary research in the fields of sustainable regional and urban development [28], [29] energy regions [30], sustainable phosphorus management [31], participation of young and marginalized citizen in urban policy processes [32], sustainable family farming [33] and ongoing research in establishing an urban food council and a (Bio)DiversityCorridor for sustainable development. Finally, we draw conclusions from these experiments by theoretically contextualizing a concept of research appropriate for a critical transdisciplinary research practice that is constituted in (cultural) difference and thereby creating a space for research in-between.

4.2 Broadening the Concept of Research

In his chapter on ethical-political foundations of interdisciplinarity[1] Felix Guattari argues for everyone's right to conduct research. To emphasize his argument, he states: "The UN Charter of Human Rights ought to include an article on the right of everyone to research" [20]. Rethinking and reframing the concept of research form part of Guattari's larger project of a generalized ecology that paved the way for an all-embracing renewal of our concept of existence [34], [35]. It introduces a way of thinking from the in-between, a form of relational thinking that is not based on monadic, static identities but rather on diastatic identities that are formed and constantly renewed in relations. In this perspective, entities and identities related to research can no longer be considered exclusive and separated, but must be seen as embedded in a broader context that is constitutive for research. This has been highlighted by science studies (e.g., Latour [14]; Gibbons et al. [11]; Nowotny, Scott & Gibbons [12]) and acknowledged by several authors who contribute to the formation of a new mode of research (e.g., Haire-Joshu & McBride [36], Jahn, Bergmann & Keil [37], Nicolescu [38], Hirsch Hadorn et al. [10], Lawrence & Després [39], Klein et al. [40]). At closer inspection, societal domains, and accordingly, tasks and roles in society, are increasingly getting blurred. Guattari speaks of a "general deterritorialization of old societal territories, ways and customs, traditions, self-regulating representations [...] and the need to balance out "the pole of a universal rationality" by enlarging the horizons of research [20] (132). Thus, rethinking and reframing the concept of research can be considered a response to ongoing societal transformations that are informed by epochal socio-technological changes. It can also be considered a response to the existential socio-ecological crisis we are facing that calls for creating

[1] Orig. Fondements éthico-politiques de l' itnerdisiplinarité, 1992 – The article of the version published in English in 2015 was re-titled ,Transdisciplinarity must become transversality'.

socially and culturally robust knowledge [41], [31], i.e., that takes “ambiguity, complexity, and contradictions [...] as fundamental features of knowledge” into account [31]. With regards to the ecological crisis, Guattari states: “Scientific ecology, applied to the environment, will remain powerless if it is not relayed by new social and political components [...].” [20] (131). Certain forms of transdisciplinary research seek to respond to this need.

Research at the science – society interface is being developed in a series of academic fields under the label of transdisciplinarity, in particular in sustainability science (e.g., Lang [42]), health science (e.g., Stokols, Hall & Vogel [43]) and development studies (e.g., Novy & Howorka [44]), among others. However, we observe that a large community of scholars – in particular those who focus on the future of the earth – stick to a concept that only relies on scientific rationality and according quality criteria and rigor. Responsibilities for transdisciplinary research remain in academic institutions, while ‘external partners’, ‘non-scientific actors’ or ‘stakeholders’ are invited to participate. These approaches often remain science-centric and are putting scientists into privileged positions in the research process, e.g., as facilitators or decision-makers [45], [46]. Often, the way language is used mirrors a mono-centric research topography by distinguishing between an active (the scientists) and a passive part (the others). Examples for this kind of unequal and fixed subject-object-relations are indicated by common expressions such as ‘to select stakeholders to integrate actors’ or ’to empower people’. This is somehow contradicting several proclaimed transdisciplinary research principles that call for balancing power by installing steering-boards [47], [28] or co-leadership [45], [42], [48], and equal footing [49], [50], [51]. And it contradicts the meaning of the prefix ‘co-’ of co-design, co-production and co-creation [52]. Furthermore, it indicates that these concepts of transdisciplinarity do not tackle the underlying epistemological and methodological consequences of such a shift in research topographies. The power of decision, the power of interpretation and, above all, the definition of good practice, quality criteria and ethics of research mainly remain with the scientists. Nevertheless, such forms of research have proven to be utile in a large variety of cases [53], [54], [31], [55], [10], [51], [56], [28], [40]. However, these transdisciplinary research practices are only the beginning of transforming the landscape and reformulating the concept of research, because “transdisciplinarity must become transversality between science, the socius, aesthetics and politics”, as Guattari states [20] (134).

When it comes to tackling pressing societal needs, when knowledge and action are needed to fight crime and poverty, unequal development, the destructionof our physical living conditions and those of non-human species, a profound transformation of mentalities is needed [20] (131). Analysis and activism, research and decision-making, as well as knowledge production and societal transformation at large can no longer remain separated. Accordingly, a profound reflection of our ways of appropriation and belonging is needed.

We envision transdisciplinary research spaces that rely on different practices, that aim at multiple objectives and connect people that inhabit different cognitive and material landscapes [59]. They may crystallize as new and explicitly labeled practices and thus form a new *topos* in the landscape of research, or they may evolve in a particular situation in an appropriate way, without becoming firmly established. Needless to say that such deterritorializations and shifts in the landscape of institutions cause resistance. Historically grown entities that are constituted in rules, norms, value systems and a particular position in relation to others are geared to stability. Thus, it is not surprising that the formation of more or less institutionalized activities that emerge between traditional institutions is contested. A current example is a debate in Germany about transformative research that addresses societal problem fields. Opponents see it as a threat to science and democracy [60], while others highlight its potential as a valuable addition to the academic system [61], [62]. However, formations and transformations occur despite academic debates. We consider a critical transdisciplinary research practice a third way of dealing with pressing challenges that also changes, on a long run, the landscape of institutions – not by rejecting the existing ones, but by complementing them. Where such activities explicitly address knowing, acting and being in a reflexive manner transversality seems to be a promising concept to describe research in-between. It aims at improving understanding and providing explanations through mutual learning [31] that serves and induces the transformation of a concrete situation. In the following, we look at transdisciplinarity through the lens of culturality to elaborate on cultural differences that become evident in transdisciplinary research.

4.3 Transdisciplinary Research: Cultural Differences and Practices

Similar to Snow's understanding of 'disciplines as cultures', several authors have underlined that culture is not only a concept that relates to nations or ethnicity [63], [64], [65]. We consider culture a process containing practices [66] which can be seen as a "set of doings and sayings" [67] (71) that consists, e.g., of bodily and mental activities, understanding, know-how, emotions, or the usage of things [68] (249). According to Hall, "culture is concerned with the production and the exchange of meanings – the 'giving and taking of meaning' – between the members of a society or group" [66] (2). Meanings indicate understandings and prioritizations and thus refer to knowledge, values, or actions. Processes throughout which meaning is produced, exchanged and negotiated are "open and unstable" [69] (26) and they are historically contingent. Cultural practices are determined by historical social and material conditions [70]. This contrasts with an understanding of culture as a static, essentialist entity often associated with notions of cultures as organic, incommensurable, or "clashing" [71].

Culture comes into being by meaningful differentiations between persons, things, or thoughts [72]. However, own cultural practices of production and differentiation of meaning only become apparent in contrast to other cultural practices. Referring to Homi Bhabha, we place ourselves in a "productive borderline space" [73] (209) that is characterized by the ambiguity of cultural differences and their transformative potential: "The borderline engagements of cultural difference may as often be consensual as conflictual; they may confound our definitions of tradition and modernity; realign the customary boundaries between the private and the public, high and low; and challenge normative expectations of development and progress." [27] (3). Such liminal spheres are prerequisites for collective processes of thought and action.

Elaborating on the concept of cultural difference, Bhabha opposes a multicultural apprehension of culture based on "cultural diversity" [27] (50) which, in his view, is a sort of hegemonic reaction to difference, forcing a consensus based on one's own norms [27]. Universal, hegemonic and normative positions from which cultural and political judgments are made fail to be unraveled [27] (209). For Bhabha, the concept of cultural diversity implies that there are the Ones deciding who is different, who belongs and who does not, who may contact whom, as well as how, by which means, and how long communication may take place. They also define cultural diversity and who fixes the Others in their role of the culturally alien. In this respect, ethic, aesthetic or ethnological categories are established and compared. Bhabha criticizes the existence of the idea of multiculturalism in which various manifestations of difference are being fixed, coexisting statically or at times replacing one another – however failing to affect each other in any profound way. The transformation processes in which people are constantly involved cannot be adequately taken into account by assuming that culture is identifiable by means of empirical, encyclopedically systematized knowledge. On the contrary, such universalistic attempts would merely dissimulate and reproduce ethnocentric values, interests, norms and racisms. Cultural contents and habits would be regarded as given facts. Rigid universal categories contribute, as Bhabha points out, only to a cultural understanding based on traditional, fixed images of the Others [73] (209ff.). His critique of multiculturalism has been echoed by Fox [74] who, among others, argues that cultural incompatibility (e.g. between values, norms, or truths) is a Eurocentric concept that is brought forward to stabilize positions of dominance and power over others.

Bhabha locates the flaw of such liberal traditions in their one-sided definition established from the angle of a hegemonic culture [73] (208). Difference, in that respect, is only perceived as valuable as long as it complies with a certain normative perception. "The concept of cultural difference focuses on the problem of the ambivalence of cultural authority: the attempt to dominate in the name of a cultural supremacy which is itself produced only in the moment of differentiation." [27] (50). With his concept of cultural difference, Bhabha examines the boundaries of preexisting myths of progress and the related supremacy of 'Western' culture. However, cultural differences are often perceived as a hurdle impossible to be overcome, impeding any exchange on the existing wealth of knowledges and practices. But it is these situations of cultural difference that, according to Bhabha, offer the opportunity of perceiving and negotiating social discrepancies and contradictions rather than ignoring them. "The question of cultural difference faces us with a disposition of knowledges or a distribution of practices that exist beside each other, albeit designating a form of social contradiction or antagonism that has to be negotiated rather than sublated." [27] (232). This is an important indication for transdisciplinary research: The better and 'more bravely' differences are allowed to be explored, articulated and negotiated, the broader a horizon for tackling shared tasks becomes. The aim of such processes is not to force consensus, but rather to highlight the problematic of prioritizing consensus by obscuring differences.

Exploring cultural differences and thereby developing cultural practices of differentiation represents a major potential for transdisciplinary research. As Gürses [75] underlines, our own cultural presuppositions and perceptions appear natural until they become possible to reflect in an act of interculturality. To perceive something as different can lead to understanding and challenging the own cultural categories and orders. However, we do not see differences as static, but *diastatic* [25], emerging in the situation of differentiation. They are gradual, prioritized, and situational [72].

4.4 In-between Spaces for Transdisciplinary Research

We will now focus on the constitution of space and show how transdisciplinary research spaces are created by elaborating on differences while sharing a joint objective. When we refer to the in-between, we use the concept of *space*. When we refer to the joint process where differences are explored and worked on and in so doing a mutual understanding emerges, we use the concept of *place* [76]. We consider them as two sides of a coin that reflect the bidirectional dynamics of differencing and integrating. Thus, space and place are not a dichotomy, but complementary concepts. Together they form a 'space-place' (*Orts-Raum*) [77]. The theoretical background of the constitution of space through differencing lies in the tradition of relational concepts of space [78]. Instead of essentializing space as a static entity, a 'container', space is considered a relational phenomenon that only exists in relations. *Through* relations and *in* relations, spaces are constituted and constantly renewed. Accordingly, they are considered as dynamic, temporal and open. In this regard, it makes a difference how relationality is conceptualized. The question is: Are these relations 'naturally given'? Are they constructed from a privileged position? Are they primordially self-constructed or do they come into existence in response to the *Other*? Instead of assuming that relations are established between different entities that already exist as *such*, we consider difference as an occurrence, i.e. emerging in differentiation. In this perspective, space is a diastatic phenomenon [25]. Relationality, that does not rely on origins, and, accordingly, antecedently existing independent entities are denied. What relates has only come into being within a relation. Thus, what appears as discrete – in our context: disciplines, societal domains, cultures, communities – is entangled and complementary. If this entanglement is addressed explicitly in researching collaboration, in-between spaces can emerge that serve a critical and culturally sensitive transdisciplinarity. Differences create a research space in which place is constituted by a web of meanings and relations. "To that end we should remember," Homi Bhabha states, that "it is the 'inter' – the cutting edge of translation and negotiation, the in-between space – that carries the burden of the meaning of culture." [27] (56).

Bhabha takes a closer look at the in-between, based on his anti-essentialist conceptualization of culture that focuses on the articulation of cultural differences, as shown above. He considers such in-between spaces a "terrain for elaborating strategies of selfhood – singular or communal – that initiate new signs of identity, and innovative sites of collaboration, and contestation, in the act of defining the idea of the society itself." [27] (2). He refers to such spaces as *Third Spaces*. Third Spaces are culturally hybrid spheres of multiple, but shared identities that are constantly developed and renewed through dialogue. Concerning the constitution of Third Spaces, he highlights the need to "think beyond narratives of originary and initial subjectivities" [27] (2). Theoretically (and politically) this is in line with Waldenfels conceptualization of responsivity. He considers the *occurrence* as primordial to the emergence of a *something* that comes into appearance in the landscape of meaning.

We argue that a Third Space can be opened as transdisciplinary research space, holding the possibility of going beyond everyday experiences, livelihoods and research practices. This creates a space of articulation in which the own, the uncertain and the differences can perpetually be fathomed, interpreted and negotiated. Existing structures, power relations and dependencies can be suspended – at least for a situational episode – when discrepancies are articulated and thereby made tangible. There is a need to explore, name and negotiate the differences. The in-between space, the gap that occurs as a result of an experience of difference, facilitates the renegotiation of identity, of creating new meaning for things, and elicits a process of constant transformation that we are all involved in. In the Third Space as a *transgressive space* [79] (235), the concept of a separating line between and within social spaces loses its one-dimensional, exclusive character [27] (5). It represents a concept of space with inherent dynamics and an understanding that enables the *un-fixing* of established positions and images [79] (53f.). Boundaries that represent the outer limits of a certain culture, political stance or epistemology move into the center of a Third Space perception.

4.5 Concluding Remarks

The practise of differentiation in transdisciplinary research is not an analytical task. No view from outside, not the best set of data, nor a 'stakeholder mapping' can achieve what emerges "*in vivo*", as Basarab Nicolescu states [80], when differences become apparent through differentiation. The occurrence of difference is irreducibly complex when the Own transforms in the formation of the Other. In order to bring differences into fruition, it is necessary that all involved become aware of the need to explicitly address them. By perceiving and increasingly becoming aware of the Own and the Others' subjugation to a certain habitus, rationals, value systems and norms, as well as the preconditions of individual thoughts and actions can be examined and questioned. This is already a shared research task that creates conditions for joint thinking and acting and at the same time mutual understanding on the different positions and perspectives. Experiencing difference becomes a reflexive process in which a particular situatedness is not merely an obstacle, but a generative principle that produces forms of social practice [68], one that constitutes the in-between.

Being determined by cultural differences, transdisciplinary research has to be considered a cultural practice in which a variety of meanings is produced, exchanged, and negotiated. The overall potential of seeing transdisciplinary research as an intercultural phenomenon is to understand the "constitution of differences" [82] (13). It leads to a reconfiguration of existing practices and the formation of new ways of research. When we explore and work on cultural differences, we can unfold a potential that is threefold: Firstly, it allows to critically (self-)reflect on often implicit premises of our thinking and working styles, norms and foundations of knowledge, and thus, on underlying social and material conditions. This can support openness as the 'unknowns' of one's own position become apparent and can thus be explained, negotiated, and defended. Secondly, dominant cultural regimes can be questioned, and positions that usually remain neglected, but might reveal a complementary perspective on the subject matter can be recognized. In consequence, a more integrated and comprehensive understanding of the subject of research can be achieved. Thirdly, collective practices can be developed that are more appropriate to understand and transform a particular situation or phenomenon of concern. As they are informed by a plurality of ways of knowing, being, acting and reflecting, they respond to complexity and intertwined conditions by being complex and intertwined themselves. However, research in the in-between, as outlined in this article, also has its inconveniences. Firstly, what has been described so far as practice of differentiation is very time-consuming. A certain degree of confidence and a language of mutual comprehension have to be developed among the persons involved in order to prepare for joint research on a shared issue. Secondly, analyzing one's own positions against the background of the Other is also not an analytical task. It requires interest, openness, empathy and willingness to learn. And last, but equally importantly, it calls for sharing power and responsibilities, which goes along with a loss of influence and control for the ones who are usually in power.

In his introduction to the essay collection '*Eine Kultur ohne Zentrum*', Richard Rorty suggests that the best practice of dealing with cultural hegemonies would be one that constantly shifts its focus depending on which group or individual just made an inspiring, original or useful contribution [21] (5). This might become a guiding principle for transdisciplinary research, a principle that acknowledges, respects and encourages differences and that does without ultimate authorities.

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CHAPTER 5

Artful Sustainability: Queer-Convivialist Life-Art and the Artistic Turn in Sustainability Research

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Artistic and arts-based research, and artful learning more generally, hold specific qualities that can contribute to the development of transdisciplinary hermeneutics. This article reviews these qualities and advocates for an artistic turn in sustainability research, as well as for a turn to a queer-convivialist life-art, enhancing the transdisciplinary experience of qualitative complexity. The article points at early signs of this turn, both in the discourse of 'convivialism' and in sustainability research & education, noticing a trend that hopefully may take up in pace and grow in scale in the coming years, allowing sustainability research to more deeply integrate arts-based research and thereby more fully realize its potential for transdisciplinarity.).

Keywords*:* Artful learning, arts-based research, convivialism, sustainability science, transdisciplinary hermeneutics.

5.1 Introduction

Over a time-span of about 20 years, alongside the rise of "sustainable development" in public discourses and of sustainability-oriented approaches in society and in the academic world, a growing number of voices have advocated, and started to practice, a variety of forms of discourses, practice and research that highlighted and exemplified the importance of artistic (e.g. [1, 2, 3, 4, 5, 6, 7, 8, 9]), aesthetic (e.g. [10, 5, 11]) and creative (e.g. [12, 13, 14, 15, 16]) approaches, and/or more generally of cultural approaches (e.g. [17, 18, 19, 20, 21]) to sustainability-oriented action and research.

The time has now come for an artistic turn in both sustainability science and sustainability activism: *Artful Sustainability* is called forward, in order to realize sustainability research's potential to develop itself in terms of "transdisciplinary hermeneutics" [22].

My aim in the following pages is not to engage in a systematic review of these precedents (and the references mentioned above are only a small sample of a much wider body of literature). Rather, I aim to take up and reflect on one argument made by several authors, which amounts to advocating for nothing less than an artistic turn for sustainability research (in and beyond academic institutions) and for sustainability activism. To do so, I will focus on two elements: First, regarding global activism, I will carry out a reading of the Convivialist Manifesto (a text which I see as a significant milestone for a sustainability-oriented civil society) in which I will be stressing an artful interpretation of its message and highlighting the manifesto's orientation to qualitative complexity. Second, regarding sustainability research, I will focus on the potentials of arts-based research, with the aim to encourage the further development of arts-based sustainability science as part of a wider transdisciplinary movement of artful sustainability-oriented research.

5.2 Promises of Convivialism and of Sustainability Science

Many civil organizations and social movements across the planet, are aiming to address the compounding contemporary threats to human civilization and working towards a more sustainable human development. A common outline for the shared features of these efforts was drawn a few years ago by the *Manifeste Convivialiste* [23], a text co-authored by several influential French-speaking left-, green- and center-left-oriented intellectuals. The Convivialist Manifesto highlighted some fundamental commonalities, shared concerns, values and approaches across a diversity of movements, and suggested several sensible orientations. I will thus engage into a commentary of this manifesto in the next section, as an opportunity to discuss the need for a queer-convivialist life-art and for an experience of complexity, as part of the transformative search process of sustainability.

Meanwhile in academia, in several European and North-American universities, a young (trans-)discipline emerged, which over the past decade became increasingly visible under the name of "Sustainability Science". This movement within academia also aims to address the compounding threats and to work for sustainable development. This still relatively-new field and form of research already developed several innovative features that bear a potential for social transformation, with a focus on solutions-oriented knowledge and action, rooted in an epistemology that does not shun from a normative self-understanding and developing an action-oriented research agenda. Sustainability Science borrows several participative and empowering features from the long tradition of participatory action-research (PAR; see e.g. Reason and Bradbury [24]), though not always clearly acknowledging it or imprecisely aiming to differentiate itself from it – and having a comparatively more fixed normative agenda rooted in the analysis of global problems of unsustainable development (whereby the researcher acquires a more 'missionary' role than usually does a PAR researcher who typically sees her- or himself as 'behind'/following social movements rather than at the helm). Sustainability Science also developed a focus on educative qualities, with many of its members aiming to build "competences for sustainability", most especially systems thinking, anticipatory, normative, interpersonal and strategic competences [25]. However, its roots in natural sciences, quantitative social sciences and systems modelling on the one hand, and its solutions-orientation spurred by a strong sense of urgency (justified by the current planetary situation) on the other hand, both bring limitations to the transformative potential of Sustainability Science. A small number of researchers involved in this field have, in recent years, started to argue, not only that "sustainability is the emergent property of a discussion about desired futures" (John Robinson in [26] p. 31), but also "that maybe the challenge of sustainability isn't to prove the world more real – rubbing people's noses in the parts per million and the hectares – but to prove the world more imaginary" (Robinson paraphrasing David Maggs, in [27]). For them, sustainability must thus ground itself beyond its traditional scientific foundation, including subjective dimensions and granting essential roles to interpretive social sciences and humanities [28]. The limitations of sustainability science can and should be addressed by an 'artistic turn' towards an artful form of sustainability research.

Addressing compounding threats such as climate change, is a challenge to work wisely with intricate combinations of knowing and non-knowing, relative certainties and uncertainties, diverse capabilities and incapabilities, hard limits and open possibilities. It is a challenge to think creatively yet humbly, containing hubris and countering the unfortunate tendency to run for quick fixes – which Gregory Bateson deplored as a society's tendency to go for the short-cuts, instead of painstakingly identifying deeper leverage points (as Donella Meadows called them). As research on climate change (and as the failure to mitigate climate change until now), shows, we need to get prepared for crises of probable much greater extent than what we have experienced so far. We will then need to get ready to develop human creative response at levels, scales and speeds probably unknown until now.

5.3 The Need for a Queer-Convivialist Life-Art and for an Experience of Complexity

As the Convivialist Manifesto made clear, the challenge of sustainability for the times to come, is not about preserving and sustaining a "good life" of the same type as what affluent societies have been enjoying for a few decades. The implications of superficial understandings of good life and sustainability, may stabilize the status quo for a few more decades to come, for some parts of the world. But in the long run for everyone (and for some sooner than for others), they will only worsen our lack of resilience. Instead of preserving good life, the search for sustainability should be interpreted as inviting us to experiment with other lives, to open up to futures-oriented questions, and to queer these other, potential (good?) lives, taking resilience as a moving horizon.

From a sustainability-oriented perspective, resilience points at the ability to survive and live well on the long term by transforming oneself in relationship with one's environments. It implies an ability to learn from, and absorb disturbances, i.e. to be changed and re-organise, to some extent, while still keeping important elements of a "same identity" (for want of a better term), or rather, keeping an ethical societal direction such as e.g. the one sketched out in the Convivialist Manifesto around principles of interdependency and care. Resilience works here as a capacity to evolve (or rather in Edgar Morin's sense, to co-evolve and eco-evolve) through serious crises. It is not just resistance, and it is not just adaptation, but involves some elements of both resistance and adaptation, without losing sight of ethical goals for sustainability. Building up the capacity for resilience will become very relevant in the coming decades, when the trusted approaches that fuelled the development of modern societies will be severely tested. Under growing instability and uncertainties, resilience will also bring better responses than any single all-encompassing strategic blueprint for transformation to sustainability. Some of my colleagues even dropped the term "sustainability", to talk about this. For example, the many space and time scales involved in this civilizational challenge brought the ecological artist David Haley to talk of a search for "capable futures" instead of "sustainability" [29]. The understanding of resilience that I am stressing here, points at the necessity to learn from the unexpected, i.e. serendipitous learning. As I argued elsewhere [6], serendipity is not merely a meeting of an open-minded perception with unexpected events, but also implies sagacity: a wisdom that is grounded in sense perceptions, and that allows keen discernment and sound judgment. The required openness also means that one should be flexible, curious and alert enough to change one's goals and interests, along the way (i.e. developing an agility when faced with options for change). Sagacity brings together sensorial perception, experiential learning over time (and over a lifetime), and acting in wisdom. Serendipity and sagacity allow not merely an accumulation of capabilities and of knowledge, as a stock of fixed items that would pile up over time. Rather, the accumulated experience actualizes itself in light of constantly changing factors. More important even than experience as the acquired stock of knowledge, is experience as the training of the capacity to perceive and interpret the world in complex ways, i.e. a phenomenological and hermeneutic learning process. This learning process requires artful qualities; else the experiential process may become a numbing, anaesthetizing one [30] that over time reinforces path-dependencies and tunnel visions rather than develop one's sagacity and serendipitous qualities.

When I look at the characteristics of resilient systems, what I see is the expression of life's inherent creativity. My contention is that, while sustainability requires both a build-up of resilience and an openness to transformative change (i.e. often radical change, going to the roots of issues and seeking deep leverage), building up the qualities of resilience in human societies calls forward a cultivation of multiple creative responses and capabilities – a radical embracing of Joseph Beuys' s provocation: "Everyone [be(come)/return to be[com]ing] an artist". Furthermore, the compounding threats discussed by sustainability researchers (and summed up in the Convivialist Manifesto), do not permit just any arbitrary form of creative development of human societies. They require a kind of cultural development that is especially sensible to qualitative complexity. My understanding of "complexity" is following Edgar Morin's, in his 6-volumes oeuvre, *la méthode* [31].[1] Although difficult to sum up in very few words, Morin's complexity can be approached by considering his notion of "macro-concepts": A macro-concept harbors the dynamic tension, both contradictory and complementary, between relationships of unity, complementarity, competition, and antagonism. Across different levels of systems, we need to learn to appreciate both the contradictions between, and dynamic balancing of, different logics, and to acknowledge the great level of ambivalence, uncertainty, and indeterminacy that all living beings have to cope with on this planet. Morin appealed,

[1] For a more thorough introduction to Morin's complexity in English language, see chapter 3 in my book Art and Sustainability [5].

metaphorically, to our “musical ears”, which allow us to “perceive the competitions, symbioses, interferences, overlaps of themes in one same symphonic stream, where the brutal mind will only recognize one single theme surrounded by noise” (Morin [31]).

One major quality of the Convivialist Manifesto lies precisely there: In its basic sensibility to qualitative complexity. Especially, the manifesto gives us some hints that “convivial” is not equated with ‘consensus-ist conformist’ political correctness, and should not drift into that direction. However, the manifesto, in its encounter with a wide readership, walks on a thin hermeneutic line: If misread in a way that is insensible to complexity, this manifesto will fall into the trap of a new form of narrow green/leftist moralism. In order to consolidate this quality that I see in the manifesto, and to help prevent the misreading I just mentioned, I will now focus my next argument on stressing ... The Importance of Being Earnest! ... Not quite. (Sustainability Science is earnest enough already.) I will focus the remainder of this section on the importance of developing an aesthetics of complexity – as a foundation stone for a practice nourishing itself in the Convivialist Manifesto and bringing an artful quality to Sustainability Science.

One area in which the manifesto expresses very well its sensibility to complexity is in stressing the balance of cooperation and antagonism (“coopÉrer et s’opposer”, [23] pp. 12, 25-26, 27). This insight echoes Edgar Morin’s understanding of complexity and philosophy of “unitas multiplex” (where any living relationship needs to be experienced through the 4 overlapping and de-re-connecting lenses of competition-cooperation-antagonism-unity). It also echoes Chantal Mouffe’s work on the importance of antagonistic relationships (and her plea for “agonistic” politics) as important dimensions of democratic practice, warning against a reduction of politics to mere consensus-based processes. This is indeed the core meaning of the manifesto’s call “to cooperate and oppose” (with) each other. This means, to both turn away from the exclusive focus on market competition which is dominant (and dwarfing cooperation) in contemporary societies, but also to prevent the very high risk of a consensus-ideology that would invariably end up into a “soft totalitarianism” (to borrow a provocative expression that I first heard – associated to a critique of consensus and the media in late 20th century democracies – in the mouth of political scientist Slobodan Milacic). Instead of a rigid dogma of consensus, convivialism needs (a) “uniplural” (Morin) culture(s) of complexity. The Convivialist Manifesto thereby does a better job at striking a dynamic balance between cooperation and opposition, than Mouffe’s own writings that privilege agonism over consensus (e.g. [32]). The need to strike such a balance is also at the core of Richard Sennett [33]’s analysis, which demonstrated how, over the history of modern Europe, different approaches to social and political participation and cooperation have been caught in a tension between ‘dialectic’ and ‘dialogic’ tendencies: In a dialectic process (in a Hegelian sense), tensions between opposing views are resolved through compromises or argumentative resolution/synthesis. In a dialogic process (in a Bakhtinian sense), different views co-exist and respect each other’s difference, whereby oppositions remain open and unresolved. The challenge of a qualitatively complex approach is not to privilege dialogic over dialectic processes as some proponents of ‘mindfulness’ may argue (or vice versa, as some proponents of agonistics may argue), but to find a dynamic balancing and negotiating process whereby both tendencies are involved with shifting dominance.

The challenge is to develop, in very concrete situations and contexts, a fine art of balancing competition, cooperation, antagonism and unity. This is indeed, not just a set of recipes with tested-and-tried techniques. It means resorting both to the consensus-fostering approach of nonviolent communication, and to the critical, deconstructive and dissensual artivistic approach advocated by Mouffe [32]. And it means resorting to the latter of course not merely towards others, e.g. some hegemonic evil forces 'out there', but also self-reflexively, as individuals, as societies and as species. It requires qualities of ambiguity, ambivalence and the "musical ear" praised by Morin, i.e. it craves for artistic competences fostering the aesthetic experience of complexity. In short, the convivialist "coopérer et s'opposer" is less a science (in the narrow sense of the term) than it is an "art de vivre ensemble" ([23] p. 14): an art of living together. This art is of course not a propagandistic, agit-prop kind of art. It is rather a continuous learning and research process with queer and discordian accents. It requires both the deconstructive and dissensual qualities found in the work of some contemporary artists, but also the reconstructive and reconnective qualities of ecological artists as I discussed them in the book *Art and Sustainability* after Suzi Gablik [5]. One example of public art attempting an interesting balancing act of these qualities, is the piece that Hans Haacke did for the Bundestag in Berlin: *Der Bevölkerung* (2000 - ongoing), a collection of soils from all German Länder (federated states), which Haacke asked Members of Parliament to contribute (New MPs were asked to bring new soil, and some soil is removed when a MP's term expires). Haacke wrote in his statement for this piece: "In an extremely controlled building, the ecosystem of imported seeds in the Parliament's courtyard constitutes an enclave of unpredictable and free development. It is an unregulated place, exempt from the demands of planning everything. It is dedicated TO THE POPULATION".

But why do I advocate for this necessary art to have"queer and discordian accents"? I will turn my earnest eye to the discordians later. First come the queer: The function of a queering artistic process is not to bring certainties, to win over your audience to your critical message, to necessarily 'make them understand' something that you already identified and thought up for yourself. It is not a Brechtian process of distanciation, elevating you into the (cold winds of) an intellectual enlightenment, and shutting down the ambiguities. The function of a queering artistic process is, on the contrary, to foster uncertainties that stimulate de-normalizing and de-naturalizing aesthetic experiences and thought & embodiment processes. It is a process of distanciation and of 'freaky desires' - to paraphrase the parlance of artist and "freaky theorist" Renate Lorenz [34], keeping you in a (warm flux of) intellectual, emotional and corporeal confusion, keeping ambiguities and ambivalences thriving for a longer moment. From such an experience can arise more interesting queerings of 'good' lives, taking us to other desires, elsewhere than within the path dependencies of affluent consumerism. We also requires a queer vigilance, to balance the "relocalisation and reterritorialization" ([23] pp. 36, 38) and the "entre soi suffisamment solide" - i.e. strong enough between-ourselves/self-segregation ([23] p. 38) proposed by the Convivialist Manifesto, with a constant reflexive work of de-normalization and de-territorialization of identities, without which the genesic potential of chaos (as discussed by Morin) would be choked off. The trick is to avoid an exaggerated parochialism and maintain the quality of what Ursula Heise [35] called an 'eco-cosmopolitanism'. We must clear out any potential confusion or misunderstanding: The Convivialist Manifesto should not be confused with some kind of communitarianism: The manifesto clearly founds itself in principles of "commune humanité [...] commune socialité [et] individuation" ([23] p. 26), i.e. Morin's three levels of human identity as individual-society-species, not reducing these to only one level. The further risk to avoid here, I would add, is ending up with an identitarian trinity of speciesm, communitarianism and individualism. Here the 'queering apart' (or 'freaking out') of these tendencies is of utmost importance. More generally, a vigilant and chronic process of queering is necessary to ward off a rigidified moralism within any convivialist-identified and/or sustainability-oriented movement. For example, from a queer-ecological perspective, the manifesto's negative take on the notion of "démesure" ([23] pp. 29, 35), i.e. excess, needs to be handled carefully, because excesses, inefficiencies of redundancies, and irrational exuberances, are important qualities of all living systems, without which no resilience could be achieved. A wholly "measured" convivialist order, forbidding "démesure", would be as foolish an enterprise as the techno-dream of efficient smart cities. The manifesto's moral warning shot hits its target more relevantly, I would contend, when it warns against "illimitation" ([23] p. 35) and "hubris" ([23] p. 29), rather than when it rejects excess.

The manifesto's second chapter proposes "four (plus one) basic questions" ([23] pp. 17ff) as "a shared "doctrinal" minimum that can fuel, sustain and legitimize an array of simultaneous answers applicable across the globe." These are the moral, political, ecological, economic (and spiritual) questions. These 4+1 questions form a meaningful set (although the "+1" spiritual question is largely left up in the air, without much discussion), but they fail to point out explicitly that any relevant moral question should be grounded in aesthetics – not in the Kantian sense but in the Deweyan sense of "aesthetics as experience" and in the Ingoldian sense of human experience – as the experience that is aliveness: a continuous movement constituting perception, as the pre-ethical basis to any moral questions we may raise: Tim Ingold considers that, at the foundation of any knowledge or ethical system that is to work in practice, is the need for intuition, i.e. a "sentient ecology" (after David Anderson), a "knowledge [...] based in feeling, consisting in the skills, sensitivities and orientations that have developed through long experience of conducting one's life in a particular environment. [...] These skills [...] provide the necessary grounding for any systems of science or ethics that would treat the environment as an *object* of its concern. The sentient ecology is thus both pre-objective and pre-ethical" ([36] p. 25 in the 2011 re-edition). The manifesto therefore fails to notice ... The Importance of Being Earnest?! Still not. (Actually, the manifesto, not unlike the discourses of sustainability scientists, is earnest enough already.) Or is it missing Sense and Sensibility? Not exactly either... But let not my course of thoughts derail just yet: The manifesto fails to notice the importance of developing senses, sensitivities and sensibilities to our environments, as multiple and interrelated modes of corporeal learning and embodied knowing, opening us up to our complex enmeshment with environments, waking us from 'anaesthesia' as coined by Wolfgang Welsch in his *Ästhetisches Denken* [30] and the associated psychic numbing. These aesthetics, i.e. these "organs of perception" (as developed by Shelley Sacks and Hildegard Kurt in their artistic work and discussed in their writings [37]), will then open up the field of perceptions-experience-knowing into enhanced qualities of questions, regarding the moral question (as well as the political, ecological and economic questions) raised by the convivialist manifesto. To be fair: some of of the points in the manifesto tangentially approach this insight, i.e. recognizing humans as "êtres de désir" ([23] p. 18) – beings driven by desire, and recognizing the importance of the "mobilisation des affects et des passions" ([23] p. 36) – mobilization of affects and passions... We need to mobilize aesthetic sensitivities to living complexity, with a convivialist-discordian eroticism.

This also means that, besides their tactical and strategic functions for mobilization and protests, "shame" and "indignation" alone ([23] p. 35), make up a poor, narrow and limited toolbox for cultural and social movements. Here, the manifesto's appeal to "affects and passions" ([23] p. 36) is highly relevant, but it also needs to be further qualified. We need to stress and articulate artistic tactics of reflexivity that are futures- and ethics- oriented, while at the same retaining qualities of ambivalence and very importantly, tactics of humor... Only with an extended toolbox, not restrained by a constricted moralism, can the bottom-bottom (i.e. horizontal) "creativity" shortly invoked in the manifesto ([23] p.36), start unfolding itself, and stimulate qualities of resilience.

After Hans Dieleman [38], I consider that resilience requires the flourishing of spaces where imagination, experimentation and challenging experiences open up futures-oriented questions and perspectives. These are both mental and physical spaces of conviviality, agonistic confrontation and other, confusing, and individually as well as socially creative, shared experiences. These are spaces where social conventions are reflected, unfrozen and challenged [5], and where imaginative and experimental practices unfold [39]. Researchers and activists alike need to engage more fully into a comparative translocal exploration of such spaces, of the functions of arts-based activities and processes therein, and of the roles of artists and other creative individuals and groups, in such spaces of possibility (see [40] for an empirical analysis on the characteristics of urban spaces of possibility). We may also explore local places as "Cthulhu-scenes" (after Donna Haraway's inspiring neologism and visions of the *Cthulhucene* as a response to the capitalism-uncritical concept of the Anthropocene [41]) - i.e. cities, suburbs, villages and other human settlements, both as naturecultural sceneries and as stages where diverse agents and 'actants' (in Latourian-speak), humans and also more-than-humans, engage (on different levels) with the multiple scales and dimensions of the search process of sustainability.

A convivialist life-art should ground itself in aliveness as the experience of complexity. It should be a creative, reflexive, critical and above all, a humorous activity. The convivialist manifesto should not be received as a stern treatise for sworn-in revolutionaries, but as an open and fundamentally democratic invitation. Seen artistically, this should be an invitation to re-invent through practice, the art of living together. An art of interdependence, of humility and also of a seriously healthy reflexive humor (as the discordians practiced it already several decades ago).

In the words of a famous systems thinker: "There is yet one leverage point that is even higher than changing a paradigm. That is to keep oneself unattached in the arena of paradigms, to stay flexible, to realize that NO paradigm is "true," that every one, including the one that sweetly shapes your own worldview, is a tremendously limited understanding of an immense and amazing universe that is far beyond human comprehension. It is to "get" at a gut level the paradigm that there are paradigms, and to see that that itself is a paradigm, and to regard that whole realization as devastatingly funny. It is to let go into Not Knowing, into what the Buddhists call enlightenment" (Meadows [42] p. 19). The one discourse I encountered, so far, that came closest to what Donella Meadows described here, is the discordians' half-serious, half-absurdist worship of chaos. But I did not really introduce the discordians yet. I kept it for the end of this section on the need for a queer-convivialist life-art and for an experience of complexity. So let me shortly (and exceptionally, else I will lose my earnest academic credentials in the eyes of some "greyfaces") defer to the (convivialist) authority of Wikipedia: "Discordianism is a religion and subsequent philosophy based on the veneration or worship of the Roman Discordia, equivalent of Eris, the Greek goddess of chaos, or archetypes or ideals associated with her. It was founded after the 1965 publication of its (first) holy book, the Principia Discordia [...] The religion has been likened to Zen, based on similarities with absurdist interpretations of the Rinzai school, as well as Taoist philosophy. Discordianism is centered on the idea that both order and disorder are illusions imposed on the universe [...] There is some division as to whether it should be regarded as a parody religion, and if so to what degree. Discordians use subversive humor to spread their philosophy and to prevent their beliefs from becoming dogmatic. It is difficult to estimate the number of Discordians because they are not required to hold Discordianism as their only belief system, and because there is an encouragement to form schisms and cabals" [43]. A few pinches of discordianism might bring some welcome seasoning to the appetizing table of convivialism. Alas, this very article is largely falling short in terms of humorous form – despite my couple of earnest attempts, clouded with declarations of utmost importance. And my earnest efforts are not over, as I now proceed to discuss what potentials lie especially in arts-based research, which could help reform sustainability research in the direction of an artful experience of complexity.

5.4 The Potential of Arts-Based Research

The potential of integrating the arts and sciences in research is especially promising in terms of 'transdisciplinary hermeneutics' [22] whereby a symbiosis between different ways of knowing the world may be developed. This understanding of transdisciplinary, based in the writings of Basarab Nicolescu [44, 45, 46], Edgar Morin [31] and rooted in the epistemological writings of Stephane Lupasco [47], is not opposed to disciplinary research, but rather to what I propose to label as a "cisdisciplinary" attitude to research. A cisdisciplinary knowing would be one that mistakes the situated and partly valid knowledge and learning made possible by any given discipline, with a complete and self-sufficient access to knowledge of the world. I am borrowing the prefix "cis-" from the term "cisgender" that refers to people who have "a gender identity or perform a gender role society considers appropriate for one's sex" ([48] p. 789). Cisdisciplinarity is an approach to disciplinary knowledge that mistakes a given discipline for an access to a complete knowledge of the world in one of its dimensions, ignoring that a discipline can merely contribute a fragmentary and situated knowledge on one dimension of reality. A cisdisciplinary way of researching is one that is satisfied with only the partial and fragmentary learning allowed by a single discipline, and construes it as a complete and autonomous, self-sufficient explanation of reality. It demands from its followers to perform a 'scientific' role that cisdisciplinary gatekeepers consider appropriate for one's discipline. Whereas the pursuit of procedural autonomy by disciplinary researchers in order to carry out research programs is an often necessary and productive practice in science, its extension into the pursuit of an ontological autonomy of disciplinary knowing, and the often-resulting epistemological and methodological sectarianism of cisdisciplinary researchers, are among the greatest harms to knowing-of-the-world that cisdisciplinary attitudes bring. Cisdisciplinary attitudes are marked by epistemological, methodological and science-political conformism. They facilitate prejudice and discrimination against ways of knowing that lie outside an established canon of respectable disciplines (which includes especially the arts and spirituality; for some cisdisciplinarians it also includes certain academic fields of studies such as gender studies or specific non-scientific disciplines such as psychoanalysis). Therefore, cisdisciplinary attitudes either oppose inter- and transdisciplinary ways of knowing, or work towards limiting inter- and transdisciplinary research to forms of collaboration between "science and society" that still maintain a strong hierarchy between the legitimate scientific knowing and the illusory 'knowing' of so-called common sense.

The "breadth and depth of knowing we associate with the full scope of human understanding" ([49] p. 82) is not sufficiently tapped into, when cisdisciplinary attitudes dominate the practice of modern science. As I articulated in the preceding pages, qualitative complexity (as theorized by Edgar Morin) is required. Already in 1983, Donald Schön argued that professionals and experts across disciplines have been experiencing, again and again, a "mismatch of traditional patterns of practice and knowledge to features of the practice situation – complexity, uncertainty, instability, uniqueness, and value conflict – of whose importance they are becoming increasingly aware" ([50] p. 18). One of the most promising features of arts-based and artful approaches to research, reaching outside of artistic professions, is to contribute to an epistemological development beyond the limitations of cis-disciplinarity, contributing to transdisciplinary hermeneutics.

Arts-based research affects our very ideas on the nature of knowledge and understanding. It introduces considerations and elements, which have been often kept out from the breadth of a researcher's access to the world. In contrast to artistic research, largely originated in art schools and art studios, arts-based research brings these new approaches and insights directly to the heart of social sciences (and sustainability science) departments where researchers take the risk to work with these approaches. Arts-based research involves the "systematic use of artistic process, the actual making of artistic expressions in all of the different forms of arts, as a primary way of understanding and examining experience" ([51] p. 29). It encompasses "a set of methodological tools used by qualitative researchers across the disciplines during all phases of social research, including data collection, analysis, interpretation, and representation" ([52] p. 1). It constitutes "an effort to explore the potentialities of an approach [...] that is rooted in aesthetic considerations and that, when it is at its best, culminates in the creation of something close to a work of art" ([53] p. 1). What characterizes research as artful or arts-based is not merely the use of specific items or elements labelled as arts (whether dance, theatre, painting, media art of other old and new formats) but rather the search for and attainment of specifically "arous[ing or] evocative" ([53] p. 41), and reflexively stimulating [54] aesthetic qualities.

Arts-based research endeavours to elicit unusual ways of thinking about social and natural phenomena, through the stimulation of uncertainty, risk-taking, and confrontation beyond superficial and taken-for-granted understandings and meanings, "broadening and deepening conversations" ([55] p. 79). It seeks new ways of asking questions and uncovers new questions to be asked ([52] p. 12). It aims to make questions and inquiry more interesting, to "stimulate problem formulation" ([53] p. 171), rather than to directly and unequivocally answer its research questions and offer some 'final' meanings, as it "revisits the world from a different direction, seeing it through fresh eyes" ([53] p. 16). In his educational and research practice, David

Haley calls it “question-based learning": With this approach, one sees the world as an expanding, meaningful inquiry, rather than as solution-led, problem-based approaches that demand closure. ‘Embodied questions’ offer diverse, creative ways of learning ecologically, as opposed to engineered or managed linear forms of teaching that exacerbate ‘wicked problems’, because they lack appreciation of complex contextuality.

Question-based learning, according to Haley, potentially offers dialogic processes, compared with dialectic, polarised ways of confronting the world and those (human and other than humans) who inhabit it. *Nevertheless*, as I already discussed above, the challenge of qualitative complexity is to find a dynamic balance between dialogic and dialectic processes. Therefore, arts-based research (and transdisciplinary research more generally) should not merely privilege dialogics over dialectics and shun away from insightful confrontations. In their questioning journey, artful approaches to research “prompt us to deconstruct assumptions” ([55] p. 143). The open space of inquiry in arts-based research is especially valuable as a corrective complement to mainstream research approaches, because it is not obsessed with a solutionist urge for the provision of answers (unlike much of sustainability science). Abandoning the claim to produce universal knowledge, arts-based research generates multiple perspectives on its research questions, rooted in multiple “attentions” ([56] pp. 37-38). Those attentions address complex and subtle interactions and they make them noticeable in the first place. This deepens our understanding of issues and makes it more (qualitatively) complex ([53] p. 3). The involvement of manifold perspectives changes the way researchers and their audiences experience situations and objects ([57] p. 128), which can stimulate innovative thinking [58].

In his work on *arts practice as research*, Graeme Sullivan highlights key characteristics of arts-based research ([49] pp. XIII ff.):

- It draws a creative tension between complexity and simplicity – this relates to a key challenge for sustainability research: addressing the immense qualitative complexity of global sustainability transformation while tracing new intervention approaches that allow participative processes beyond small circles of already highly involved agents. The apparent self-contradictory double-goal of maintaining and even cherishing qualitative complexity (“we must learn, not to be afraid of complexity”, as argued by ecological artist David Haley [59]), *and* of finding simplicity and elaborating simple forms, is one challenge that artists and arts-based practitioners are long acquainted with: “not oversimplifying complex issues, and [...] finding ways to be challenging whilst not being off-putting” ([55] p. 76).
- It places much focus onto venturing into and exploring the unknown, allowing the emergence of new knowledge, and taking a fluid approach to knowledge-generation. “Arts practice as research opens up new perspectives that are created in the space between what is known and what is not. Traditional research builds on the known to explore the unknown. Art research creates new possibilities from what we do not know to challenge what we do know” ([49] p. 244). Unlike the proverbial scientist searching for his keys in the night, not near where he may have dropped them but near the nearest lamp post, artists and arts-based practitioners are often willing and even motivated to explore into the darkness (and even sometimes into the murky and uncomfortable depths of the *Heart of Darkness* of human soul and society [60]), helped by a creative searching, learning and shaping (Gestaltung) process that allows

ambiguity and ambivalence.

- It converts a process of search and analysis into the telling of a story – not unlike scientific research, but with much more awareness of the subjective authorship at stake in the process of telling a story.

Knowledge generation in artistic process is nourished by "imaginative investigations" ([49] p. XII) that articulate constellations of possible meanings, allowing a large freedom of 'lateral', associative thinking around lived experience. Especially the analysis and interpretation of data in arts-based research should be "systematic and rigorous but also inventive so as to reveal the rich complexity of the imaginative intellect" ([61] p. 20). This imagination is not purely speculative. The empirical ground of an arts-based research process is to be found in sensory perceptions and in a reflexive relationship to one's perception of the world, which bears great similarities with the phenomenology of perception (hence many artists' sustained interest in Maurice Merleau-Ponty's *Phenomenology of Perception* [62]). This implies a heightened awareness of the multiple levels and processes of interpretation at play in perception and further cognitive and inter-subjective communicative processes. Artists and arts-based practitioners are often especially sensible to the framings of and influences on perceptions and interpretations by personal biographies, cultural frames and social constructions of reality (even though some sociologists like to believe in their privilege or monopoly over social reflexivity). They are also sensible to the influence of immediate contexts and importance of the situations where perceptions and interpretations take form. They thus recognize interpretation as a dynamic and interactive process ([49] pp. 15 ff.). This high self-reflexive awareness that arts-based approaches bring the researcher, are a powerful way to address the challenge of re-uniting the Subject and Object, overcoming their undue separation in modern science. In the arts-based research process, both the observer and the observed are considered "as legitimate sources of knowledge in any inquiry" but are also to be held under continuous critical scrutiny ([49] p. 52). The "convenient fiction" of objectivity ([49] p. 38) is then replaced by an intersubjective process of assessment and valuation of the potential artistic expressions ([49] pp. 39 ff.). Here, arts-based approaches can be brought together with hermeneutic methods. For arts-based research, the dialogue with audiences of artistic expressions gains higher importance than in some traditional formats of artistic production and consumption: This dialogue assigns meanings and includes multiple perspectives, further enriching the research process. The researcher is also part of this dialogue and must include her or his own emotions too ([52] pp. 18 ff.).

Artistic practice bears the capacity to both question+reflect+critique the construction of knowledge, and to allow the emergence of new understanding (cf. [49] p. 96). The insights gained thereby sheds light on that which "might otherwise be beyond words", as argued by both Barone and Eisner, and Savin-Baden and Wimpenny ([55] p. 76), thanks to "expanding the various descriptive, explanatory and immersive systems of knowledge that frame individual and community awareness" ([49] p. 97). Arts-based research aims to generate a broader knowledge-range, involving especially tacit knowledge, e.g. as knowledge experientially generated in-action ([50] p. 49) – revealing, beyond denotative words, that we are "knowing more than we can say" ([50] p. 51). Produced artworks are "a site where knowledge is created" ([49] p. 71), and so are artistic processes [63], as these works and processes embody tacit knowledge (see also [64]). Arts-based research also involves contextual knowledge ([49] p. 71) through reflection about the cultural and biographical conditions of the artistic inquiry, a.k.a. situated knowledge as discussed below with Donna Haraway. At this juncture, some arts-based researchers point at an issue, “whether knowledge is found in the art object of whether it is made in the mind of the viewer” ([49] p. 83). Here, I would argue against a reduction of knowing to either of these two alternatives, instead following Tim Ingold’s views on perception and knowing as a meshwork of movements where both the subject and the others (labelled by Ingold not as ‘objects’ but as ‘things’) actively encounter each other, affecting each other’s lines of movement: “an issuing along with things in the very processes of their generation; not the trans-port (carrying across) of completed being, but the pro-duction (bringing forth) of perpetual becoming. ... To be sentient ... is to open up to a world, to yield to its embrace, and to resonate in one’s inner being to its illuminations and reverberations. Bathed in light, submerged in sound and rapt in feeling, the sentient body, at once both perceiver and producer, traces the paths of the world’s becoming in the very course of contributing to its ongoing renewal” ([65] p. 12). Furthermore, artful knowing involves specific qualities in experiential learning: The quality of sensory-based perceptions and learning can be sharpened, deepened, and differentiated through the training of aesthetic observation and exploration, allowing more distinctive experience (cf. [66] p. 115). Next to this, the otherwise tacit and subconscious processes by which ideas and terms are associated to images in the mind, come closer to the surface and can be subjected to interference and change thanks to arts-based practices (cf. [67] p. 211). All these qualities can sharpen a sensibility to qualitative complexity (see also Kagan [5] on the need for ‘aesthetics of complexity’ in the context of transdisciplinary sustainability research).

In arts-based research, the choice of specific methods-mixes is usually guided by the research questions, not by the disciplines ([55] p. 46) – it is “inquiry-based” rather than discipline-based, as is the case in any truly transdisciplinary research project (Cf. [68]). Therefore, the research incorporates findings and methods from other research approaches, with a fluid and pragmatic take on epistemology, e.g. not necessarily ignoring research rooted in positivism; it tolerates epistemological pluralism, again allowing another dimension of complexity (cf. [49] pp. 100 ff.). It also brings many own methods originating from a variety of artistic practices, largely untapped by other research approaches, such as e.g. ethnodrama and performance ethnography where dramatic forms allow to merge research and representation ([55] p. 55), dance where the researcher and participants’ bodies are the vessels of a corporeal searching, experiential learning and embodied knowing, and the “tool through which meaning is created” ([52] p. 183), or poetry, storytelling and other creative written narratives that stimulate wider interpretative processes than usual denotative language with relatively more prescriptive meanings ([52] p. 259; [49] p. 205; [55] p. 129). Arts-based research projects do include stages that bear resemblance to traditional scientific research processes: data collection, analysis, interpretation and representation ([52] p. 12). The process often does not neatly proceed linearly from one stage to the next, but rather usually proceeds both in iterative cycles and with parallel, simultaneous and/or hybrid processes and stages ([55] p. 63). Sullivan even rejects the qualification of “iterative” for artful processes, as he differentiates their “cyclical, emergent and discovery oriented” characteristics, from the “linear, iterative and confirmatory” characteristics of processes typically found e.g. in quantitative social research ([49] p. 192). Interpretation and representation are often enmeshed with each other, as already hinted at above, and there are “more overlaps between data collection and data interpretation than in other forms of qualitative inquiry” ([55] p. 46). This also involves “iterative relationships between the issue, the context, the researcher and the participants” ([55] p. 28).

Patrica Leavy replaces arts-based research in the context of qualitative social science, recalling the epistemological shifts already brought about by qualitative research: “Qualitative researchers do not simply gather and write; they compose, orchestrate, and weave” ([52] p. 11). In this tradition, the active, meaning-making, interpretative role of the scientist was recognized, as the social sciences experienced successive ‘linguistic’ and other cultural ‘turns’ ([49] p. 18). For example, the ethnographic tradition of Clifford Geertz’s “Thick Description” [69] already stressed the creative and imaginative (and sociologically speaking, the fictional) qualities of the research process. Leavy thus considers arts-based research as “a new breed of qualitative methods” for social sciences, able to approach topics which involve existential conceptual dimensions such as love, death, power, memory, fear, loss, desire, hope and suffering. These dimensions constitute “some of the most fundamental aspects of human experience” ([52] pp. 3 ff.) and should be also highly relevant to researchers engaged for sustainability, as they matter greatly in relation to attitudes, motivations, desires, dispositions to believe, and dispositions to act, at the individual and community levels. Furthermore, not only to investigate, but also to communicate research findings around these aspects of human experience, artistic and arts-based forms of expression can be especially “emotionally and politically evocative, captivating, aesthetically powerful, and moving” ([52] p. 12). Leavy insists on the potential power of the arts to communicate the emotional aspects of social life ([52] p. 13). This is one argument that scientists are prompt to acknowledge and focus on when thinking about the use of the arts in research, though too often in a narrowly instrumentalist and impoverished way – as the other qualities and the epistemological challenge of arts-based research (as they are sketched out in the text) are ignored. Two critical remarks are warranted, regarding Leavy’s claim:

- On the one hand, as the sociology of the arts has demonstrated in much details for several decades – from the works of Pierre Bourdieu and Richard Peterson to those of Bernard Lahire and many others, different art genres, forms and styles reach only specific sections of a society, according to cultural capital and other determinants of aesthetic consumption patterns (see e.g. Lahire [70]). No art-form is therefore having a universal outreach to an entire society.
- On the other hand, the arts are not merely good communicators of emotional dimensions of reality, but offer also especially media to develop emotional intelligence and gain a probably deeper experiential knowing of these dimensions (whether directly or vicariously with works of fiction; see e.g. Weik von Mossner [71, 72]).

Given that there exists as of today, no “consensus about what should count as quality” across the great variety of existing arts-related research approaches ([55] p. 52), and that each arts-based research project needs to find its own relevant set of quality-criteria, an in-depth discussion of the issue is beyond the scope of this text. However, some potentially helpful suggestions are made by Barone and Eisner, with a set of 6 general criteria that can be considered, together with wider concerns of ethics and aesthetics: incisiveness (revealing the core of an issue), concision (that allows a previously unknown perspective to be perceived), coherence (between the parts and the whole of the inquiry), generativity (enabling to see phenomena beyond single cases, and to potentially act upon them), social significance (thematic relevance and importance for social change), evocation (reaching understanding beyond logico-deductive explanations) and illumination (deeper insights on a single topic) ([53] pp. 148-154). Regarding possible ethical criteria across different forms of arts-related research, Savin-Baden and Wimpenny ([55] pp. 86 ff.) suggest to look into matters of ownership, reflexivity, negotiated meaning, transparency, plausibility, honesties, integrity, verisimilitude, criticality, stance, authenticity and peer evaluation.

Overall, arts-based research not only brings new methodical elements that allow an enriched interdisciplinary research work, especially for qualitative social sciences. It also requires that the researchers learn and develop new sets of competences and skills that help scientists research the complex unity of the world beneath, between and beyond disciplines, as advocated by Basarab Nicolescu [44], contributing to the development of transdisciplinarity. Indeed, artful approaches to research aim not merely at explaining phenomena, but at gaining an understanding of phenomena ([49] p. 96), exploring subjects in more existential human depth than usually done in scientific research.

Arts-based research (and other forms of arts-related research) share an epistemological ground with Donna Haraway's epistemology of "situated knowledges" and of an "embodied objectivity" [73] i.e. an epistemology where knowing grounds its validity in its situatedness and partiality, rather than in the claim to reach universality by speaking from nowhere (or from an imagined "control tower", as already deconstructed and denounced by Morin [74]). Haraway insists on the differences and multiplicity of local knowledges ([73] p. 579). Arts-based research encourages this multiplicity, where other methods tend to restrain it. Arts-based research invites individual, personal, subjective perspectives and experience (of the researched, the researcher and the audience) as legitimate and central dimensions. On the one hand, subject and object are not split but united in vision, as advocated for by Haraway ([73] pp. 581 ff.). On the other hand, Haraway also calls forward a recognition of our "split and contradictory self", i.e of a multidimensional subjectivity: "The knowing self is partial in all its guises, never finished, whole, simply there and original; it is always constructed and stitched together imperfectly, and therefore able to join with another, to see together without claiming to be another" ([73] p. 586). Arts-based approaches, which unfold and allow ambiguity, polysemy and/or ambivalence, are an ideal vehicle to bring about this recognition. Leavy echoes Haraway very closely (without citing her) when she writes that "arts-based practices produce partial, situated and contextual truths" ([52] pp. 15-16 ; see also [56] pp. 37-38). However, recognizing one's partial position is not sufficient, a critical self-reflexivity is required, as advocated by Haraway as well as by arts-based researchers (e.g. [55] pp. 45, 48). As argued by Haraway, positioning is required, and thus arts-based researchers have to reflect on their position in the creation of knowledge, throughout the research process, including a reflection of political and epistemic contexts. In doing so, artful approaches allow an expanded reflexivity that is not only logico-deductive but is "more than rational" ([75] p. 109) in its integration of hermeneutic, aesthetic, ontological and professional reflexivities – i.e. of reflexivity through the deconstruction of meaning-routines, the re-articulation of perceptions and forming (Gestaltung), the revisiting of being and existence, and an experiential knowing-in-doing (cf. [75]; see also [50]). Furthermore, artistic reflexivity takes on a specific quality insofar as "a healthy scepticism and ironic posture" is often found and expected too ([55] p. 33), as attitudes that keep reflexivity in a state of near-constant sharpness. Another requirement that Haraway stresses, in the feminist epistemological tradition, is the recognition of the research objects' activity (vs. research objects considered as inert and/or passive). As discussed above, arts-based research fulfil this requirement too (as does any proper transdisciplinary research), in its attention to the multiple perspectives of the researched, researcher and audiences. The resulting, redefined 'objectivity' according to Haraway is rooted not in a claim of neutral distance but in "contestation, deconstruction, passionate construction, webbed connections and hope for transformation of systems of knowledge and ways of seeing" ([73] p. 584). Here, Haraway suggested a bold endeavour and agenda with even clearer accents than done by most arts-based research advocates (whereby I remain sceptical about the terminology of 'objectivity', preferring the earlier-mentioned terminology of intersubjectivity when discussing the networking of partial perspectives).

5.5 Outlook: Practicing Artful Sustainability Research & Education

Lazy readers expect to find a summary of the main ideas and insights from an article or paper in its conclusion. I will not comply with this convention here. Instead, I prefer to use the final paper pages to address those readers who did read the whole paper I close this text with two threads of outlook: (1) a few words about those colleagues around the world who are already developing the transdisciplinary practice of artful sustainability research today; and (2) a brief commentary of how artful sustainability as I proposed it in this text, relates in both complementary and contrasting, unitary and opposing ways, to Dieleman [22]'s interpretation of transdisciplinary hermeneutics.

Studies on of the roles of the arts in relation to sustainability-related issues are being published every few years for already more than a decade. See the published reviews on the roles of visual, performing and community arts for environmental sustainability (Curtis et al. [76], Blanc and Benish [9]), of ecological art for sustainability (Blanc and Ramos [4], Kagan [5], Weintraub [8]), of literature and cinema from the perspective of ecocriticism (see e.g. Zapf [77]), of music in relation to sustainability (Kagan and Kirchberg [78]), and reviews focusing more specifically on the roles of literature (Johns-Putra [79]) and the arts (Galafassi et al. [80]) regarding the challenge of climate change. However, reviews of arts-based approaches as they are already being practiced by sustainability science researchers themselves, are rarer and emerged only more recently: see for example Heras and Tàbara [81] on the uses of theatre-based participatory tools and methods in sustainabilty research projects.

For my part, my efforts at the Leuphana University Lüneburg, from 2005 to 2017, most often in collaboration with Volker Kirchberg and/or further colleagues, have included multiple projects integrating arts-sociological, cultural-scientific, arts-based and inter- and trans-disciplinary approaches, combining research with higher education. Among the specific arts-based and arts-related approaches I employed are Identity Correction (after the Yes Men), documentary film-making, trans-situ art installations (with the CCC of Geneva Art University), transect walks (after Martin Kohler), walks with video (after Sarah Pink), performative interventions in public space, and systems games (originally developed by Dennis Meadows and Linda Booth Sweeney) modified in order to bring some element of qualitative complexity. Further formats and approaches were developed by my colleagues and students throughout our research projects (related to performative re-enactment, creative writing, photography, theatre of the oppressed, contact-improvisation dance, and further approaches). In summer 2010 I directed the “International Summer School of Arts and Sciences for Sustainability in Social Transformation" (ASSiST, Gabrovo, Bulgaria) with a focus on the transdisciplinary development of walking-based place-making methods, and in summer 2016 another international and transdisciplinary summer school on “Artistic and other Creative Practices as Drivers for Urban Resilience” (in Espinho, Portugal, co-directed by Nancy Duxbury) with a focus on urban practices that create spaces of possibilities for sustainable urban development.

In November 2016, a coalition of (mostly early-career) sustainability researchers working with arts-based research organized an international symposium at the Institut d’Estudis Catalans and Autonomous University of Barcelona, entitled “Realizing Potentials: conversations and experiments at the frontier of art-based sustainability". Further universities co-organized this gathering: Universitat Oberta de Catalunya, Societat Catalana de Biologia, Universidade de Evora, Universidad Pablo Olavide Sevilla, and University of Hohenheim (suggesting the emergence of some meagre institutional for these approaches). The event included a series of practical arts-based research workshops, and I was invited to give the keynote speech on “Artful Sustainability: The artistic turn in sustainability science" (which overlapped with some of the points I am discussing in this paper). Several dozen researchers from around the world presented their current arts-based research projects in fields of environmental sciences and sustainability science.

New Higher Education programs emerge that focus on artful sustainability research. For example, the federal university of São João del-Rei (in Brazil) opened a postgraduate program in ‘Arts, Urbanities and Sustainability’ that started offering a Master in 2016, rooted in the university’s transdisciplinary research group in ‘arts, cultures and sustainability’ initiated in 2013 by Adilson Siqueira. The ‘PIPAUS’ MA places a strong emphasis on artivism, "based on an expanded definition of art that follows the redefinitions of art conceived not as a formal act but as an intervention in society, so that the artist works in interdisciplinary community teams and artistic creativity is no longer an act of isolation" (PIPAUS website, own translation from the Portuguese: https://ufsj.edu.br/pipaus/informacoes_gerais.php). This postgraduate programme is, to my knowledge, one of the very few and first in the world to integrate urban studies, sustainability research and arts-based research. It is being taught by fourteen professors from five Departments: Literature, Arts and Culture (DELAC: Literature, Theater and Social Communication); Architecture, Urbanism and Applied Arts (DAUAP: Architecture and Urbanism and Applied Arts-Ceramics); Natural Sciences (DCNAT: Biology); Zoology (DEZOO); and Administrative and Accounting Sciences (DECAC). The programme enables its students to “collaborate in the society-nature relationship mediated by communication, technology and the field of applications in order to contribute to the sustainability agenda" (PIPAUS website).

These are only a few examples, but they may be early signs of an artistic turn in sustainability science, which hopefully may take up in pace and grow in scale in the coming years, allowing sustainability research to more deeply integrate arts-based research and thereby more fully realize its potential for transdisciplinarity.

Artful Sustainability, as I elaborated over the preceding pages, corresponds largely to Dieleman [22]’s interpretation of "transdisciplinary hermeneutics" that he claims "will change science into art" (Dieleman [22]: 197) - “an art rather than a science, because it has the potential to make us combine what is with what may be, and what is measured with what is felt and intuited" (Ibid: 180). Most especially, the interplay of different approaches to knowledge production is a primary goal of transdisciplinary hermeneutics and of artful sustainability, as is the recognition (after Morin and Nicolescu) that reality is complex and discontinuous and that the dimensions of the subject of knowing (through “cognitive knowing, embodied knowing and enacted knowing") are as important as, and to be related to, the dimensions of the object of knowing (e.g. as an object of study, as a (philosophical) idea, as a creation and as an experience). Artistic and arts-based research not only combine cognitive and embodied knowing both for their practitioners and audiences, but also develop enacted knowing for all participants who are actively involved at some level of arts-related performance, through the enactment of roles and situations (not only strictly in performing arts but also through other forms of artistic expressions). Scientific writing is insufficient and “artistic forms are necessary to capture the results of processes of perceiving and sensing, which are essential parts of team-based transdisciplinary hermeneutics" (Ibid: 196). The thereby constituted “transdisciplinary approach gives room for the simultaneous existence of multiple truths" (Ibid: 178). Artful Sustainability, as I advocated in this paper, does give this room, as well as it strives to “constantly question the knowledge we develop in terms of its possible biases, which are not only rooted in the way we think and analyze, but equally in the way we see, feel and act" (Ibid: 179).

Dieleman [22] focuses on two “key competencies" to learn to master transdisciplinary hermeneutics: mindfulness and dialogue. He sums up the qualities of these two approaches, pointing out their value as correctives to the limitations and dangers of unreflected habits and de-contextualized (modern-scientific) discussions. However, notwithstanding their qualities as correctives, some limitations and dangers are associated with mindfulness and dialogue as well.

I acknowledge that mindfulness (in principle) allows developing “a state of heightened consciousness of our own physical experiences, feelings and thoughts [and] find[ing] a new equilibrium between brain, body and environment, overhauling the dissociation of the brain from the body and of awareness from experience" (Ibid: 191). Nevertheless, as I experienced over recent years over a variety of situations, the current spread of the practice of mindfulness, in its concrete implementation, is placing consciousness and awareness on a pedestal, leaving too little space to subconscious flows of the body-mind, sometimes even suffocating intuition while praising it and strangling creativity while invoking it. I saw some of its advocates effectively perpetuating a delusional imaginary of control (though replacing cybernetic and technocratic control with mindful self-awareness) and also developing a simplistic imaginary of reaching harmony by appeasing tensions and avoiding conflicts. Dieleman [22] makes a convincing plea for mindfulness as a competency that allows practitioners of transdisciplinary hermeneutics to know through the use of the bodily senses, and emotions. However, it is important to mention that the opposite should be accomplished to what now usually is achieved in some mindfulness practices: Instead of realizing merely a mindful control over the body, one should realize a state in which the mind also serves and follows the body. This is only implicitly present in Dieleman’s latest article and should be stressed more explicitly.

As to dialogues, it is important to mention a different shortcoming and danger. I already warned at several points earlier in this paper against a one-sided privileging of dialogics against dialectics. Further warnings against the uncritical use of this approach can be found among (self-)critical accounts of practices of “Nonviolent

Communication" after Marshall Rosenberg, which stress the consequences of dialogical approaches that leave no genuinely legitimate space for contradictory tensions and conflicts ([82, 83, 84]). The acceptance of multiple truths then turns into an a-political escapism towards avoidance and denegation-suppression of direct tensions. Ultimately, if left unchecked and unbalanced by other approaches, this a-political practice may end up contributing to a soft-totalitarian form of consensus-ism. On the contrary, arts-based approaches can allow tensions and conflicts to be expressed and reflectively processed in non-oppressive *and* non-censored ways, if they take care to avoid the a-political biases that loll in mindfulness and nonviolent communication.

Dieleman [22] concludes that transdisciplinary learning and knowing, when it moves in between levels of reality, "allows us to see unity and connectedness [as] a capacity we create inside of us" (Ibid: 197). It is what Nicolescu calls the "Included Third" as a way to realize unity in knowing and surpass the fragmentation of knowledge. I second that but once more, I need to emphasize that such unity and connectedness must explicitly be seen as "uniplurality" within qualitative complexity, without tipping into any form of holistic simplification. Artful Sustainability is convivial *and* discordian. This is why a crucial quality of artistic and arts-based approaches is to maintain tensions, discomfort, irritations and challenging experiences at all levels of reality. An approach that would be merely content with certain currently practiced forms of mindfulness and dialogics and tend towards a-political practice, would fail to address the deep injustices perpetuating global unsustainable development. A qualitatively complex transdisciplinary imaginary of sustainability needs to associate ontological, epistemological *and* political imaginations.[2]

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[2] These are three of the four imaginations described in Kagan's characterization of four "imaginaries of sustainability" in sustainability research [85].

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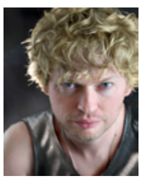

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CHAPTER 6

Towards an Indigenous Transdisciplinarity

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This chapter attempts to theoretically position and characterise an indigenous (Māori) transdisciplinarity in relation to (i) the transdisciplinary methodology of Basarab Nicolescu and (ii) mode–2 transdisciplinarity (i.e. the Zurich Model). This writing outcome is achieved by drawing attention to the existence of a 'cultural continuum' of knowledge development in which contemporary western science (entire) is viewed as one of an estimated 6,900 culturally mediated approaches to knowledge development that exist on planet Earth today. Recognition of the role of 'culture' and 'indigeneity' in knowledge development is shown to be essential, if we are to avoid the extinction of an estimated 50–90% of the world's current linguistic (cf. cultural) diversity over the next 100 years. As a first step towards characterising an indigenous transdisciplinarity, this chapter explores the knowledge development traditions of New Zealand Māori, as drawn from the experiences of the author and writings of pūkenga Māori (transl. Māori scholars).

Keywords*:* Indigenous transdisciplinarity, Transdisciplinary methodology, Cultural survival, Kaupapa Māori, Mode–2 transdisciplinarity.

6.1 Introduction

This chapter draws on key characteristics of New Zealand Māori cultural identity and experiences in research to define what I describe in English as an indigenous (Māori) transdisciplinarity. The existence of an indigenous transdisciplinarity follows from the well-established fact that indigenous peoples have ways and means of knowledge development that differ from those employed in western science [1-3]. This difference has been highlighted by published literature on 'decolonising methodology' that is now contributed to by a growing number of indigenous scholars worldwide [4-7]. Much effort has been invested over the last 3 decades in developing the western scientific methodology and practice of transdisciplinarity [8-11]. By contrast, literature that compares and/or contrasts western scientific and indigenous perspectives on transdisciplinarity is difficult to find. This chapter draws on my teaching, learning and involvement in Māori communities to create an initial step towards the theoretical and methodological characterisation of *an indigenous (Māori) transdisciplinarity.*

The contents of this chapter are important because Māori and other indigenous cultures are a taonga tuku iho (transl. inherited treasure). While indigenous cultural survival is both feasible and desired, key survival (and wellbeing) indicators have been in decline for a long time [12]. Indigenous cultural survival and wellbeing are dependent on the continued use and adaptation of indigenous knowledge development traditions. Just how these knowledge traditions can find freedom of expression and co-exist with western science is a matter of grave concern given current and projected levels of cultural extinction. Furthermore, to achieve the goal of indigenous cultural survival, a number of pre-conditions are necessary. First, the free, daily expression of cultural language, values and institutions within functioning cultural ecosystems and landscapes. Second, the ability to adapt to change using creativity (incl. knowledge creation) and respond to disturbance events in ways that reclaim, reframe and reinstate essential cultural identity.

Cultural survival and wellbeing pre-conditions have proved very difficult to maintain during colonisation events. In New Zealand, the process of colonisation began in the mid 1840s and saw the rapid introduction and domination of a foreign language, religion, economy, approach to education and knowledge development [13]. Concerted pushback against these colonising influences was initiated in the mid 1970s with the revival of the Māori language. This was followed by efforts to decolonise state education in the 1980s and disciplinary science in the late 1990s [14-21].

Publication of the book ‘Decolonising Methodologies’ by Linda Tuhiwai Smith [22] represents an important milestone in the efforts of Māori communities and scholars to get recognition for the existence of a distinctive Māori cultural approach to knowledge development. Additional impetus was given to the work of decolonising ‘education’ with the writings of Brazillian born, Paulo Freire, whose book ‘Pedagogy of the Oppressed’ [23] and thinking on educational reform was eagerly embraced by Māori communities, academics and activists [24-26]. This decolonising watershed of the 1970–90s provided Māori communities, activists and scholars with the knowledge and tools needed to begin reclaiming their ancestral knowledge and reframing it in a modern-day Māori cultural approach to knowledge development (i.e. ‘kaupapa Māori[1] research’). While literature that focuses on the decolonisation of disciplinary science is well-established, the relationship between kaupapa Māori research, indigenous knowledge development and transdisciplinarity is only just beginning to be explored [27-29]. This chapter proposes an initial outline of this important theoretical landscape.

This ‘theoretical’ gap in contemporary indigenous knowledge development needs attention for a number of reasons. First, in academic terms, the holistic character of inidgenous knowledge development is difficult to justify and financially resource, when its legitimacy and relevance is constantly measured against an existing western scientific preoccupation with disciplinary specialisation. Second, as shown in this chapter, while not identical, there are similarities between the creation of mātauranga Māori (transl. Māori knowledge) and the transdisciplinary methodology of Basarab Nicolescu (2005). Furthermore, the written scholarship of Basarab Nicolescu provides a thoughtful, well referenced and articulate critique of the limitations of classical western scientific methodology. This critique is of central importance to decolonis-

[1] Transl. ‘knowledge creation grounded in Māori cultural identity’

ing discourse. Third, transdisciplinarity is part of the emerging frontier of western science that aims to provide a more holistic approach to joint-problem-solving and collective knowledge development. An opportunity now exists for Māori and other indigenous scholars to understand and influence the methodological development, real-world and experimental applications of transdisciplinarity so that it does not become *yet another colonising influence on indigenous peoples* [30]. At present, this is a very real concern given that decolonising discourse appears to be largely missings from current transdisciplinary literature.

6.1.1 Linguistic limitations

The first challenge in any attempt to characterise what might be referred to in English as an 'indigenous transdisciplinarity' concerns our use of language in attempting to communicate 'meaning' across cultural boundaries. According to Nicolescu [9], the name 'transdisciplinary' comes from the language of western science and is believed to have been introduced by Jean Piaget (1896–1980). Concerning the meaning of transdisciplinary, Nicolescu [9] explains that in its English rendering, the word 'transdisciplinary' refers to that which is across, between and beyond the disciplines. In this linguistic construction of transdisciplinarity, the pre-existence of (western) academic disciplines is a 'fixed' reference point for categorising different approaches to the coordination of knowledge development - across, between and beyond disciplines. While there is no linguistic analogue for the English word 'transdiscplinary' in Te Reo Māori (transl. the Māori language), this is not to say that the 'meaning' of transdisciplinary knowledge development was foreign to my tūpuna (transl. Māori ancestors). Thus a challenge in this area of written scholarship is to compare 'meaning' across cultures, rather than just 'vocab'. Use of the English term 'indigenous transdisciplinarity' has been adopted in this chapter because it is a useful means of communication with *western scholars*, a reference point that can be used to *compare and contrast* the knowledge development experiences of indigenous peoples with those of their 'western' counterparts.

If we shift our attention away from 'vocabulary' towards 'meaning' it is possible to show that the antecedents of modern-day transdisciplinarity can be traced back (historically) into former inidgenous cultural contexts [29]. Thus, from an indigenous cultural perspective, the emergence of transdisciplinary methodology and practice in western science might, respectfully, be considered as a relatively recent innovation, *when compared with indigenous knowledge traditions.* A failure to recognise the many and varied contributions of indigenous peoples towards holistic knowledge development appears to exist, because western scholars are still coming to terms with the idea that knowledge development is 'culturally mediated' (ref. section 2).

The middle English word 'culture' is a loan word that is believed to have come from the German 'kultur' and the Latin 'cultura'. According to Newbigin [31], the English notion of 'culture' as a distinctive race of people really only entered into English vocabulary and consciousness during the 20th Century. This relatively recent conception of differing races of people challenged earlier ecclesiastical notions of a universal 'family of God' and imperialist notions of 'human civilisation' [31]. From an anthropological perspective, culture can be characterised by the existence of unique (pre-analytic) worldview perceptions; assumptions and beliefs about reality that are encoded in language, of which there are a documented 6,900 in existence today [12, 32-35].

In seeking to translate indigenous languages into English, the existence of direct linguistic analogues (i.e. similar vocab, grammar and written expression) that can be used to accurately transfer 'meaning' across the English/indigenous language divide is rare. Thus, an approach toward 'indigeneity' from the vocabulary and metaphysical foundations of western science is difficult *at best*. An aim in writing this chapter is to try and show that the transdisciplinary methodology of Basarb Nicolescu [9] provides a helpful theoretical and axiomatic foundation, within western science, for dialogue and collaboration with Māori culture (and potentially other indigenous knowledge traditions). An additional pre-requisite for those wishing to build dialogue and collaborative activities with indigenous peoples is the adoption of indigenous language competency. Therefore, to assist readers, reference to Māori language in this chapter is supported by in-text English translation [36, 37], even though this interpretive reading aid often fails to capture the full richness and nuances of a Māori worldview.

While clearly challenging, this language translation problem is also profoundly important for transdisciplinary endeavour because the existence of linguistic discontinuities provides evidence of fundamentally different pre-analytic worldview conceptions, assumptions and beliefs about the nature of reality. In particular, indigenous cultural conceptions of reality are characteristically holistic (cf. 'transdisciplinary') in nature [38, 39].

6.1.2 Scope and Limitations of This Chapter

This chapter draws on the writings of Māori scholars and my own experiences in teaching, learning and working with Māori communities to 'generalise' and theoretically position a Māori cultural approach to knowledge development [40-42] in relation to: (i) the transdisciplinary methodology of Basarab Nicolescu (i.e. the Nicolescuian Model) and (ii) mode-2 transdisciplinarity (i.e. the Zurich model), [10]. While generalisation is commonly used in western science as an aid to categorisation, its use in indigenous cultural contexts is problematic because it tends to over-simplify a social reality that is rich, diverse and complex. Thus, this written contribution is very much a first step towards understanding.

I offer this written contribution as a scholar from New Zealand of Māori descent. I was initially trained in the western science tradition, but in 2005 I began a personal journey in 'decolonising' much of what I was taught at university. One aim of this journey was to better understand how my tūpuna (transl. Māori ancestors) developed knowledge to support the survival and wellbeing of their whānau (transl. the Māori family ecosystem). The English word 'family' is limited in capturing the meaning of the Māori concept of 'whānau'. In Māori culture, the concept of whānau is holistic and inclusive. The whakapapa (transl. geneaology of 'whānau') describes an 'ecosystem' rather than a nuclear family. This Māori ecosystem is composed of Papatūānuku (transl. our Earth mother), Ranginui (our Sky father), Atua (transl. the children of Papatūānuku and Ranginui) who are the kaitiaki (transl. guardians, caretakers) of the different domains of the natural world and Tangata Whenua (transl. Māori commnuities) who are the teina (transl. younger siblings) of this 'ecological' Māori family. This 'whānau Māori' identity is profoundly important.

By today's standards, the survival of whānau Māori (transl. the Māori family ecosystem) on the New Zealand island archipalego for approximately 800-1,000 years, prior to the onset of British colonisation [13] was a remarkable achievement. This is especially because my tūpuna (transl. Māori ancestors) managed to maintain their physical survival along with the survival and wellbeing of the entire Māori family ecosystem. By comparison, these same goals are very difficult to achieve in a modern-day capitalist market economic context. Thus, understanding the knowledge development traditions of my tūpuna (transl. Māori ancestors) is an important contribution towards the future survival and wellbeing of our culture.

6.2 The Cultural Mediation of Knowledge Development

Before an attempt is made to compare and contrast western scientific and indigenous perspectives on transdisciplinarity, it is first necessary to explain in what way 'knowledge development' is culturally mediated. We live in a period of human history in which mode–1 disciplinarity (i.e. an adaptation of classicial western scientific methodology) has become dominant and mainstreamed. Western scientific thought is taught in state schools and plays a critical role in the innovation engine that drives modern economic growth. The dominance of western scientific thought, methodology and method is underpinned by decades of *remarkable achievements* that have had both positive and negative effects on human and ecological wellbeing. In summary, it seems fair to say that western science works well in its own *cultural context*, where it promotes the survival and wellbeing of its own (i) worldview assumptions (cf. axioms), (ii) ontology (e.g. English, mathematics), (iii) values (i.e. ethics, desired outcomes, codes of professional conduct) and (iv) epistemology (i.e. methodology, methods). Western science is an emerging 'cultural entity'. When combined with its own disciplinary elaboration of market economics, western science has become a surrogate 'culture' for a large part of the world's population. The need for cultural surrogacy of this kind is a direct consequence of decline in pre-existing cultural identities; leading to the extinction of the world's former cultural diversity.

While western science seems to work well in its own cultural contexts, its application in indigenous cultural contexts can result in unwanted outcomes that contribute to *cultural decline and extinction*. Western scientists have been slow to come to terms with this problem, the existence of which does not imply that western science is somehow wrong. However, it is unhelpful to view western science as superior in terms of its knowledge achievements or knowledge development methods. Western science does not provide a 'benchmark' for measuring the relative worth or value of non-western scientific knowledge traditions that are essential to human (cultural) survival (entire). Knowing, the sacred and culture are integral parts of human identity that find expression in daily life. The violent separation of classical scientific method from religion and culture was, at the time, a necessary but incomplete step. The emergence of a methodology of transdisciplinary is therefore, in evolutionary terms, an urgent and necessary adaptation or re-adjustment for western science.

However, western scientific knowledge is not an appropriate solution to *every cultural survival and wellbeing problem*. Human knowledge creation is *culturally mediated* and the free expression of different culturally mediated approaches to knowledge development is closely linked with the goal of cultural survival. A central goal of 'decolonising methodology' has been to obtain recognition for the legitimacy of culturally mediated worldviews, languages and approaches to knowledge development. The role of culture in mediating knowledge development is also a pre-requsite assumption that is needed to define and position an indigenous transdisciplinarity. Such an assumption is necessary because if we assume that western science is superior (i.e. the most valid model of knowledge development), then there can only ever be one 'superior' methodology of transdisciplinarity. Because this point is central to the conclusions of this chapter, the remainder of this section is devoted to a more detailed consideration of why it seems reasonable to propose that western science is only 1 of an estimated 6,900 culturally mediated approaches to knowledge development that exist on planet Earth today [12].

6.2.1 The Aetiology of Western Science

What we today refer to as 'western' science is one small part of an accumulated knowledge continuum that has been contributed to by scholars of different cultural origins for thousands of years. The varied contributions of these scholars laid the foundations for the western scientific revolution. For example, it was the Sumerians who gave us the earliest forms of symbolic language [43]; the Babylonians who contributed to early forms of mathematics, astronomy [44-48], philosophy and the arts; the Persians who developed orderly government, complete with centralised administration, systems of communication and transport [49]; Ancient Greece gave us the first pre-industrial economy along with remarkable advances in philosophy, government, law, literature, astronomy, mathematics, medicine, technology, art and systems of education [50-61]; the Roman Empire developed Republican government along with advances in law, economics, architecture, engineering, literature, education, medicine and the arts [50, 61-73] while finally, scholars of the Islamic Golden Age provided a linguistic bridge for the transfer of learning from Antiquity into Turkish, Hebrew and Latin languages. Islamic scholars also made remarkable advances in philosphy, mathematics, the natural sciences, engineering, medicine and the arts; advances that laid an important intellectual foundation for the western scientific revolution [74-79].

While terribly incomplete, this somewhat abbreviated, and yet remarkable history of 'culturally mediated' human knowledge development is a result of at least three pre-conditions that provide an important perspective from which to think about how we define 'western science'. First, human intellectual achievements have always been culturally mediated. Second, knowledge development needs freedom of expression because discontinuities in culture caused by war and other disturbance events interrupt culturally-mediated knowledge development processes, even though they can also provide opportunity for adaptation, novelty and innovation. Third, human contributions to knowledge developmemnt are not only culturally-mediated, they create culture in ways that transform reality. Cultural survival and wellbeing is both a 'cause' and 'consequence' of human knowledge development. This point is so important that it deserves further elaboration.

As far as we understand, from an western scientific perspective, the ability of humans to create knowledge sets them apart from other members of the animal kingdom. Humans are able to visually perceive and sense, reflect upon and change our perceptions of reality, with respect to time, in a way that grows knowing that we are able to store in memory and re-access. We have the ability to name, classify and group objects of visual and sensory perception in a way that creates a spatial (i.e. internal/external) awareness of our interaction with reality. While every human being is born with this innate capacity for knowledge development, the cultural context into which we are born provides an interpretive lens that strongly influences how we see the world and what knowledge we create [23].

Worldview is a sub-conscious collection of axiomatic reference points, or fundamental assumptions and beliefs about the nature of reality that we use as a pre-analytic basis for visual and sensory perception, reflection, evaluation and knowledge development. For the most part, we never question the validity of the worldview assumptions that are passed onto us as a consequence of the cultural context into which we are born. However, we are capable of becoming aware of inconsistencies in our worldview assumptions when we are provided opportunity (i.e. *through natural experiments*) to observe what happens when our worldview assumptions are pushed to their logical limits. While we generally assume that our worldview assumptions are irreducible (i.e. essential), correct, appropriate and valid (i.e. the way we see the world is a correct way to see the world), it is important to note that our worldviews are culturally mediated abstractions of reality, which in evolutionary terms, are adapted to a cultural and ecological context in which our survival and wellbeing must be achieved. Thus, worldview is itself, *partly a product of culture*.

Our worldview perceptions are encoded in the unique language of our culture. Language is the ultimate 'ontological' framework of (Māori[2]) culture that provides a fascinating insight into our worldview assumptions [12, 80]. We name what we perceive, while what we percieve is a logical consequence of our worldview assumptions. As such, language provides a useful diagnostic tool for inferring worldview assumptions. The distinctive language of a culture provides ontological building blocks, for the creation of knowledge through the use of culturally distinct epistemologies. Cultural knowledge is used on a daily basis to give expression to agreed cultural practices (i.e. values) which through the amazing creativity of culture transforms our world (Figure 6.1) in ways that create distintive 'cultural ecosystems, landscapes and nation states' [81]. A number of important conclusions follow from this thesis of culturally mediated, knowledge development activities.

First, human contributions to knowledge development are inextricably linked with our worldview. Furthermore, we are generally not aware of the extent to which our sub-conscious worldview assumptions and beliefs influence (i) how we 'see the world' and (ii) the nature of the knowledge we create. Second, culturally mediated knowledge development expands the expression of our cultural identity in ways that validate, refine and in some cases, fundamentally change that cultural identity. Cultural identity is constantly evolving and knowledge development thus plays a critical part in this process of change.

Third, it is important to re-iterate that every human being is born with an innate capacity for knowledge development. This is what might be referred to as 'knowledge development at its raw edge'. It is not necessary to obtain a PhD from university in order to become qualified to make knowledge development contributions to the survival and wellbeing of your culture and its distinctive identity.

Finally, our perceptions of reality are encoded in language that provides the ontological building blocks for knowledge creation. This point is important because there are a documented 6,900 languages in the world today [12]. This fact implies that there are also, at least, 6,900 different worldviews, perceptions of reality, knowledge traditions and cultural expressions of these systems of knowledge development that

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[2] A well known statement of Sir James Henare to the Waitangi Tribunal in 1989 clearly articulates this thought "Ko te reo te mauri o te mana Māori" (transl. language is the life force or energy of Māori).

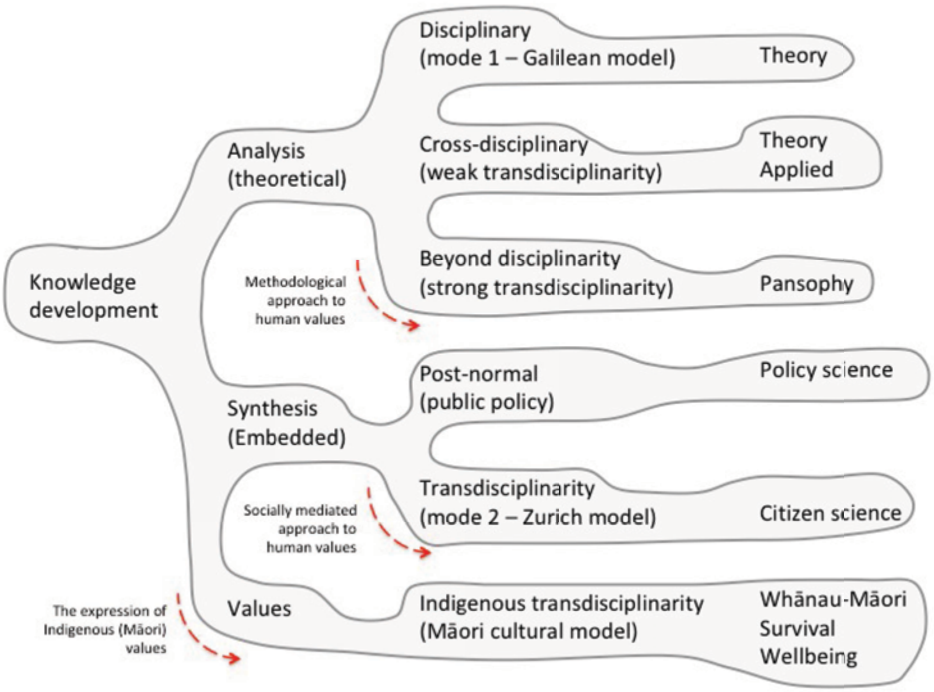

Figure 6.1: A visual depiction of the current theoretical landscape of transdisciplinarity.

are responsible for the human cultural transformation of our world. In theoretical and methodological terms, this is *the cultural landscape of transdisciplinary knowledge development*.

Yet for some reason, we seem to have come to a time in human history in which there is an implicit, unquestioned assumption, that has become almost axiomatic among western scientists (i.e. that mode-1 western scientific methodology is 'the reference point' from which all other contributions to knowledge development should be evaluated or in some cases dismissed).

> *"In western cultures, to be involved in non-scientific knowledge production is to place oneself beyond the pale, so that there is, today, a distinct sense of social isolation associated with participation in a non-scientific activity..."* [82, p. 2].

One of the defining challenges of 'decolonising' disciplinary science in New Zealand has involved an ongoing struggle for recognition of the legitimacy of a Māori cultural approach to knowledge development, education and spirituality [42]. This struggle is still very much 'work-in-progress' as is demonstrated by the following quote from a New Zealand Government policy document published in July 2007 that carries the name 'Vision Mātauranga: unlocking the innovation potential of Māori knowledge, resources and people'.

> *Scientific knowledge has superseded traditional Māori knowledge in many ways, however, Mātauranga Māori contains suggestions and ideas that may yet make a contribution to research, science and technology (RS&T),* [83, p. 16].

This statement is problematic for a number of reasons. First, the idea that *mātauranga Māori contains suggestions and ideas that may yet make a contribution to RS&T* implies that *research, science and technology* is 'the reference point' to be used in assessing the relative worth or value of Māori knowledge. This begs the question of why it is not possible to use Māori cultural values and criteria to measure the worth or value of *Māori cultural contributions* to Māori knowledge development.

Second, western scientific knowledge is presented in this statement as having *superseded* traditional Māori knowledge. This claim ignores the fact that western science is itself only 1 of a documented 6,900 languages and culturally mediated approaches to knowledge development that exist in the world today [12]. To accept that western science has superseded one or all of the other 6,899 culturally mediated approaches to knowledge development begs the question of what criteria is being used to draw such a conclusion. How can we say, that one culture's worldview and perceptions of reality are in some way better or worse than another?

The role of culture in mediating the development of knowledge is important for another reason. An estimated 46% of the 6,900 languages that exist in the world today are at risk of extinction. What current research indicates, is that we are loosing one of these 6,900 languages, on average, every 3 months[3], so that within the next 100 years, we currently stand to loose somewhere between 50–90% of the world's current linguistic diversity [12]. Knowledge development is not just an end in itself. It supports the survival, continued evolution and wellbeing of human cultures. This knowledge development *outcome* is also important. It is within this cultural survival and wellbeing context, that justification exists for mapping the 'transdisciplinary' knowledge development experiences of different cultures and especially indigenous cultures.

6.3 The Landscape of Transdisciplinary Knowledge Development

When it comes to transdisciplinary knowledge development and joint-problem-solving [84], the distance between indigenous cultures and western science might not be as far apart as we might have previously assumed. This realisation was first impressed upon my mind during the 2^{nd} World Congress on Transdisciplinarity in Brazil (2005), while listening to Basarab Nicolescu describe and explain his methodology of transdisciplinarity. I was surprised at the level of similarity, of resonance and signature that existed between Nicolescu's methodology of transdisciplinarity [9] and the knowledge development thinking and experiences of my tūpuna (transl. Māori ancestors).

[3]This estimate was derived from research completed by the Endangered Language Catalogue (ELCAT) project of the University of Hawaii. The initial findings of this research were presented at the 3rd International Conference on Language Documentation and Conservation in 2013. An online blog titled 'New estimates on the rate of global language loss' explains the derivation of this estimate and is avilable on the Rosetta Project website (http://rosettaproject.org/blog/).

Following the 2005 Congress, I read more widely on this topic and set myself to the task of attempting to characterise, and theoretically position these two knowledge traditions. With time, I gradually came to the realisation of distinct similarities and differences that made possible the characterisation of what I have referred to as an indigenous (Māori) transdisciplinarity. I have used the term ‘indigenous’ to suggest that the knowledge development traditions of my tūpuna, share similarities with other indigenous cultures. I have attempted to visually depict the current *theoretical landscape of transdisciplinarity* in Figure 6.1 and will devote the remainder of this chapter to explaining the significance of this illustration.

Figure 6.1 focuses attention on the problem of ‘knowledge development’. I use this name to include theorising, joint-problem-solving, experimentation and value-based approaches to knowledge development. Irrespective of the specific methods, or means used to create knowledge, Figure 6.1 recognises the existence of 3 main pathways of knowledge development (i.e. analysis, synthesis and values). Two of these pathways are well-known to western scientists (i.e. analysis and synthesis) and one is well-known to Māori and other indigenous peoples (i.e. a value-based approach to knowledge development). These 3 pathways can be used to theoretically position, 3 different approaches to transdisciplinary endeavour.

First, in Figure 6.1, the analytical tradition can be characterised by 3 further pathways of knowledge development that have emerged as gradual adaptations of western scientific methodology (i.e. mode–1 science), as initially formulated by Galileo Galilei and others at the time of the western scientific revolution. This includes: (i) the emergence of distinctive areas of science and disciplinary specialisation, (ii) the co-ordination of knowledge development across and between the disciplines (i.e. what Max-neef [8] characterised as ‘weak transdisciplinarity’) and (iii) the simultaneous co-ordination of knowledge development – across, between and beyond the disciplines (i.e. what Max-neef [8] characterised as ‘strong transdisciplinarity’).

These 3 pathways are characterised by distinctly diferent goals. The creation of theory is the primary goal of disciplinary science, whereas the creation, and real-world application of theory is the primary concern of cross-disciplinary studies. Finally, the emergence of a methodology for the co-ordination of disciplinary knowledge development across, between and beyond the disciplines has opened a space for the unification of knowledge as a most recent adaptation of western science. I have characterised the ‘strong transdisciplinary’ goal by the use of the term ‘pansophy’ that appears to have been first used by Jan Amos Comenius (1592–1670). It was the life-long ambition of Comenius to write what he called a ‘pansophy’ – a thesis that attempted to unify all knowledge. Comenius is known to modern educationalists as the ‘Father of modern education’ and in addition, appears to have been one of our early ‘transdisciplinary’ scholars [85-88].

An important characteristic of the 3 pathways of ‘analytical knowledge development’ depicted in Figure 6.1, is that its most recent innovation – the transdisciplinary methodology of Basarab Nicolescu (2005) – provides a methodological approach to the explicit reunificiation of western scientific object and subject.

Second, in Figure 6.1, the synthesis tradition of western scientific knowledge development can be sub-divided into 2 additional pathays. The ‘post-normal science’ [89] and ‘mode-2’ pathways [82, 90-92], are further adaptations of classical western scientific methodology that provide additional approaches to the coordination of knowledge development across the disciplines. These 2 approaches have been spatially positioned as quite separate from the transdisciplinary methodology of Basarab

Nicolescu. The reason for this separation is because the transdisciplinary methodology of Basarab Nicolescu is both an adaption of western science and a critique of the limitations of classical western scientific methodology.

By contrast, post-normal science and mode-2 transdisciplinarity are based on an explicit assumption, that classical western scientific methodology is basically correct and does not therefore need revision, but application in new and novel ways [10]. Nicolescu has attempted to achieve the re-unificiation of the scientific subject and object through the creation of a new methodology for western science. By contrast, post-normal scientists and mode-2 transdisciplinary scientists attempt to achieve a co-creation goal, through the social mediation of scientific knowledge development (i.e. the explicit inclusion of disciplines, stakeholders and communities in the research process). While the methods used by mode-2 transdisciplinary researchers and post-normal scientists differ, the overarching goal is to extend the coordination of knowledge development – across and between the disciplines – into the realms of (i) policy-making (i.e. policy science) and (ii) joint-problem-solving (i.e. citizen science). In Figure 6.1, I refer to the synthesis pathway of western science as 'a socially mediated approach to human values'.

Finally, an additional pathway for knowledge development is depicted in Figure 6.1, based on the explicit use of indigenous values as a means of creating knowledge. The analytical and synthesis pathways of Figure 6.1, depict the existence of differing adaptations of classical western scientific methodology that have been created in order to achieve the re-unification of scientific subject and object. An additional goal of the transdisciplinary methodology of Basarab Nicolescu has been the re-unification of knowledge. By contrast, the third pathway, located at the bottom of Figure 6.1 involves an approach to unified, holistic knowledge development, that is based on the expression of indigenous values. I have characterised this approach to knowledge development as 'indigenous transdisciplinarity' [93]. It is somewhat awkward and difficult to position an indigenous transdisciplinarity in theoretical proximity to the analytical and synthetic traditions of western science, because these 3 knowledge traditions do not share – to use western scientific language - a common linguistic basis. However, as noted earlier in this chapter, I am increasingly impressed at the extent to which there are similarities of 'meaning' between indigenous transdisciplinarity and the transdiciplinary methodology of Basarab Nicolescu [9].

While listening to Basarab Nicolescu present his transdisciplinary methodology at the 2nd World Congress on transdisciplinarity, I had a sense of inner resonance, I could begin to see the visible signature of something with which I was already familier. Basarab Nicolescu explains this experience as communication between 'levels of perception' and 'levels of reality' that is made possible by the 'T-state' or 'included middle'. Assuming this is correct, then it seems appropriate to describe the theoretical positioning of 'indigenous transdisciplinairty' in close proximity to western science, as the positioning of what western science has considered to date, to be logical contradictory pairs (i.e. A and non-A). The use of exclusive logic in this way seems appropriate given that it has been nothing short of a major struggle, for indigenous peoples to obtain recognition from western science as to the legitimacy of their knowledge traditions *for no other reason than they are non-A* (*i.e. not western science*). Yet, as I have attempted to show in this paper, western science does not hold a competitive monopoly on knowledge development when it comes to the problem of human *cultural* survival. This logical contradiction between the exclusive entities ('A' western science) and ('non-A' indigenous knowledge traditions) might finally be able to be reconciled through Basarab Nicolescu's logic of the included middle [9].

The goals of indigenous transdisciplinarity (Figure 1) seem to differ from those associated with western scientific methodologies. I am of course, most familiar with the experiences of my tūpuna (transl. Māori ancestors) in this regard. The central goal of Māori culture involves maintaining the survival and wellbeing of whānau Māori (transl. the Māori family ecosystem). To solve this survival and wellbeing problem, my tūpuna (transl. Māori ancestors) created what might be thought of (in English) as 'Māori universal values' (transl. kawa, kaupapa) [94]. A distinguishing characteristic of kaupapa (transl. Māori universal values) is that their daily expression sustained the survival and wellbeing of all members of whānau Māori (i.e. the Māori family ecosystem). When compared with the ecological destruction that has been associated with the application of western scientific knowledge over the last 170 years, the survival of my tūpuna (transl. Māori ancestors) on the New Zealand archapeligo for 800–1,000 years, before European settlement and colonisation was nothing short of a remarkable achievement. My reading of published literature, and in particular the most recent contributions of indigenous decolonising theorists, suggests that the survival and wellbeing experiences of my tūpuna (transl. Māori ancestors) over the last 1,000 years is consistent with the experiences of many other indigenous peoples. An elaboration of the experiences of my tūpuna (transl. Māori ancestors), and comparison with the trandisciplinary methodology of Basarab Nicolescu, is outlined in the 4th and final section of this paper.

6.4 An Indigenous (Māori) Transdisciplinarity

In this final section, I compare and contrast the knowledge development experiences of my tūpuna (transl. Māori ancestors) with emerging thinking on transdisciplinarity. In pursuing this writing goal, I cannot speak on behalf of Māori culture (entire), or all indigenous peoples. This paper is but a first step towards describing and theoretically positioning an indigenous (Māori) transdisciplinarity. It is written as a scholarly contribution towards dialogue between the western academy and the work of indigenous/Māori scholars and their communities.

The English word 'indigenous' is generally used to refer to one of two different meanings. When applied as a noun to human culture it generally refers to a genealogically related group of people whose identity is partly defined by an intimate inter-relationship with the natural world. When used as an adjective, it can be applied to any entity (including people) that originate 'naturally' in a particular place. While the English word 'indigenous' has been adopted by some Māori scholars [94], there are others who avoid the use of this English label. As a description of Māori culture, the meaning of indigeneity can be limiting in a way that fails to capture the unique and remarkable character of those human societies that have evolved distinctive cultural identities, in association with the Earth's island, forest, river, coastal, desert, arctic, marine, estuarine, wetland and grassland ecosystems.

As noted earlier in this chapter, in exploring transdisciplinarity across cultural boundaries, it is the transfer of 'meaning' that is important. I agree that the English word 'indigenous' is limiting. However, its reference to the human≡nature identity relationship, as a basis for cultural evolution, is a 'meaning' that is widely understood [95]. For this reason, I have used the term 'indigenous' as an English language approximation of a more complex, human social-cultural-ecological-spiritual reality [96-99] that is profound and worthy of our deepest respect.

In Figure 1, I have proposed that 'indigenous transdisciplinarity' is based on the expression of indigenous cultural values [100]. Before comparing and contrasting this approach to knowledge development with the transdisciplinary methodology of Basarab Nicolescu, it is important to explain the significance of an approach to human cultural knowledge development that is 'value-based'. As noted earlier, Māori scholars refer to this approach to knowledge development as 'kaupapa Māori research' [101] where the word 'kaupapa' has many possible 'contextual' meanings including the 'values of Māori society'. In the time of my tūpuna (transl. Māori ancestors), the goal of Māori knowledge development focused on the survival and wellbeing of whānau Māori (transl. the Māori family ecosystem). My tūpuna devised a plan for the achievement of this goal, that was based on the creation of 'kaupapa' or what might be explicitly defined in English as 'Māori (universal) values'. These values were passed across generations as kaupapa tuku iho (transl. inherited Māori values) and expressed through Māori behaviour called 'tikanga' (transl. right ways of doing things).

Kaupapa tuku iho (transl. inherited Māori values) are generally recognised by all Māori communities, however their expression as tikanga (transl. right ways of doing things) varies according to context, and to some extent the preferences and creativity of local Māori communities. Thus, kaupapa (transl. Māori cultural values) are 'universal' in the sense that all Māori communities recognise that these values form a basis for maintaining the survial and wellbeing of whānau Māori (transl. the Māori family ecosystem). For this reason, the daily expression of these inherited values in the form of tikanga (transl. right ways of doing things) forms a preferred basis for Māori knowledge development [102]. This approach to knowledge development ensured that knowledge discoveries were consistent with, or adaptations of, Māori cultural values and right ways of doing things. This in turn maintained the survival and wellbeing of whānau Māori (transl. the Māori family ecosystem).

Our tūpuna created, adapted and refined their kaupapa over a very long period of time as part of their knowledge development activities and in an attempt to discover what mixture of values would ensure the survival and wellbeing of Māori communities and what western scientists refer to as 'the natural world' (transl. whānau Māori). As noted above, these values have withstood the test of time, including 800–1,000 years of isolation on the island archapeligo of New Zealand, prior to British colonisation. The knowledge development activities of my tūpuna involved much more than the discovery of universal values. Their quest for survival and wellbeing led them to explore the mysteries of the universe, including what western scientists refer to as the 'quantum world'. While much of this escoteric knowledge has been lost as a conseuqnece of colonisation, wonderful insights still remain and provide a window into the world of Māori knowledge development before British colonisation (1840-). To illustrate this point, the following quote is presented. It was written by the late Rev. Māori Mardsen, who was privileged to have been one of the last of his generation to have attended the Whare Wānanga (transl. Māori schools of higher escoteric learning). Attendance at Whare Wānanga provided first hand access to the escoteric knowledge of our tūpuna (transl. Māori ancestors). After returning from overseas duty during the second world war, Māori Marsden recorded the following conversation.

> *After the war, when I returned to the Wānanga I was questioned by*

> *the elders of the Wānanga about my war experiences. In the course of my sharing our experiences I mentioned the atom bomb. One of the elders who had of course heard of the atom bomb asked me to explain the difference between an atom bomb and an explosive bomb. I took the word 'hihiri' which in Māoridom means 'pure energy'. Here I recalled Einstein's concept of the real world behind the natural world as being comprised of 'rhythmical patterns of pure energy' and said to him that this was essentially the same concept. He then exclaimed, "Do you mean to tell me that the Pākehā scientists (tohunga Pākehā) have managed to rend the fabric (kahu) of the universe?" I said "Yes" "I suppose they shared their knowledge with the tūtūā (politicians)?" "Yes" "But do they know how to sew (tuitui) it back together again?" "No!" "That's the trouble with sharing such 'tapu' knowledge. Tūtūā will always abuse it."* (103, p. XIII)

How is it that my tūpuna (transl. Māori ancestors) were able to discover these (visually) hidden secrets of the quantum world, long before the tohunga Pākehā (i.e. western scientists) grappled with the troublesome discoveries of the quantum revolution in the 1920s [104-106]? While there is much that could be written in reponse to this question, in this chapter I want to focus on three significant factors (i.e. cultural identity, isolation and epistemology).

First, concerning cultural identity. In Figure 6.2, I attempt to visually show that my tūpuna arrived at what I refer to as indigenous (Māori) transdisciplinarity as a result of their 'animistic' identification with the 'natural world' as a genealogical extension of the human Māori family. By contrast, what I have attempted to characterise in this chapter as 'western culture' came to transdisciplinary methodology and practice as a result of attempts to extend (i.e. post-normal science and the Zurich model), [10, 89] and remedy (i.e. transdisciplinary methodology), [9] classical western scientific method. The journey of 'western culture' to classical scientific and transdisciplinary methodologies was mediated – not by 'indigeneity' – but by what I characterise as an 'urban ecology' (Figure 6.1). The concept of an urban ecology stands in contrast to the Māori family ecosystem. An urban ecology is a generalisation and abstraction of a more complex and so-called 'civilised' society [107] that used the creation of complex urban or city environments as evidence evolutionary superiority [31]. Thus, indigenous and western scientific transdiciplinarity have distinctly different aetiologies.

Second, concerning isolation.[4] The evolution of western society over the last 3,000 years occurred primarily in the northern hemisphere. Reference to the modern-day preface 'western' denotes the emergence of a contemporary cultural identity from interaction among many geographically related cultural entities. Modern 'western' society is a culturally co-created phenomenon. By contrast, my 'tupuna' lived in relative isolation from this turbulent cultural evolution in the northern hemisphere. They dwelt on island ecosystems in the southern oceans. This home afforded then a wonderful 'natural laboratory' and opportunity for knowledge development that was not influenced by 'western' thought.

Finally, concerning epistemology. The latest methodological developments in western science (i.e. transdisciplinary methodology) shares similarities with the

[4]I am deeply grateful to my whānaunga and rangatira, Whatarangi Winiata for drawing my attention to this important dimension of the whānau experiences of my tūpuna.

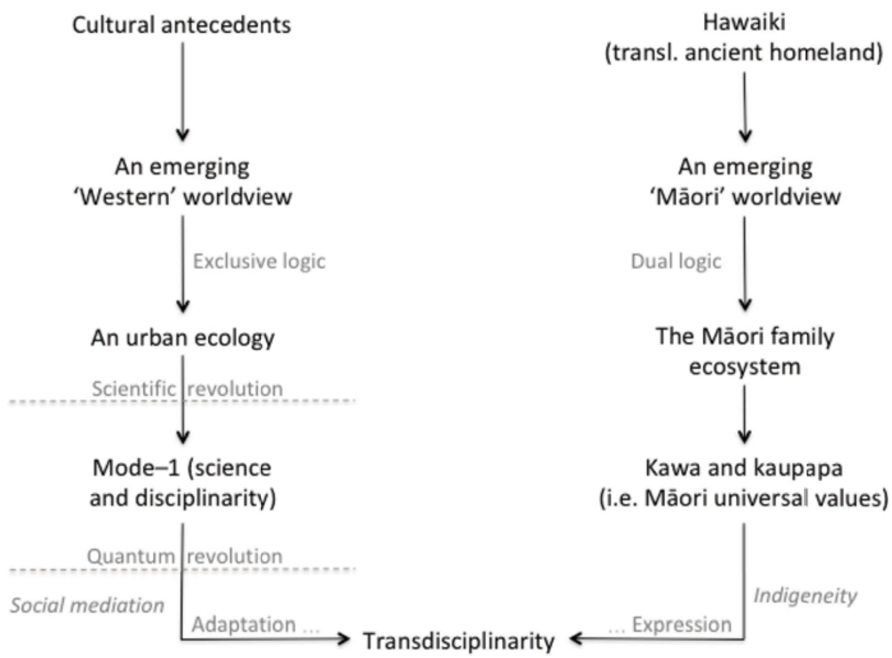

Figure 6.2: A visual depiction of 2 different evolutionary pathways to transdisciplinarity.

knowledge development traditions of my tūpuna. I hesitate to refer to indigenous transdisciplinarity as a 'methodology' because it involves an approach to knowledge development that is – in one sense – distinctly different to that of western science (i.e. based on the expression of inherited Māori (universal) values), [108]. My use of the word 'methodology' is only to draw attention to the existence of similarity. Thus, this linguistic concession is for the benefit of communication with western scientists and not as an ontological contribution towards mātauranga Māori (transl. Māori knowledge). While indigenous transdisciplinarity is distinctive, it is possible, through the logic of the 'included middle' proposed by Basarab Nicolescu, to align this Māori cultural 'reality' with certain levels of western scientific perception. To explore this included middle: (i) I comment (below) on the unification of classical scientific subject and object and then (ii) I use the transdisciplinary axioms of Basarab Nicolescu [9] as a conceptual and theoretical reference point (i.e. sub-section headings) for 'sketching' a written outline of indigenous (Māori) transdisciplinarity, drawn primarily from the writings of the late Rev. Māori Marsden [103].

6.4.1 On the Unification of Classicial Scientific Subject and Object

I often pondered why my tūpuna (transl. Māori ancestors) saw no need for a written language. There is much that could be written in comment on this question. However, an important point is that the knowledge development goals (i.e. the survival and wellbeing of the Māori family ecosystem) of my tūpuna (transl. Māori ancestors), required the creation of systemic, holistic knowledge in which subject–object–sacred are unified. A real challenge faced by my tūpuna (transl. Māori ancestors) was how to communicate subject–object–sacred knowing of this kind from one generation to the next – with accuracy. This problem was solved with the aid of oral communication [109]. Written language is a discretised, simplificiation of reality, much like the number system in mathematics. It cannot easily be used to communicate subject–object–sacred meaning from 'writer' to 'reader' without introducing the problem of human perceptual complexity. By contrast, oral language, when used in conjunction with communication aids (e.g. time, location, experience, smells, tonal variation, facial expressions and guestures) can transfer subject-object-sacred meaning more effectively [110].

My tūpuna (transl. Māori ancestors) were masterful in their use of oral language in conjunction with other communication aids that were used to transfer knowing that embodied subject–object–sacred dimensions. Māori oral language was also expressed in numerous symbolic forms including toi (transl. artistic expression), haka (transl. a form of dance), waiata (transl. lyric and melody), pakiwaitara (transl. stories), pūrākau (transl. myths, legends), whakapapa (transl. genealogies) and whakatauākī (transl. wise sayings). My tūpuna (transl. Māori ancestors) saw no need for a strictly objective knowing of reality [103, p. 2]. Their approach to reality was collectively mediated, systemic, distinctly holistic and deeply profound. As such, their systems of knowledge development along with the storage and transfer of subject–object–sacred knowing across generations aligns with what Basarab Nicolescu [9] identitifed as a core goal of transdisciplinarity (i.e. the re-unification of scientific subject and object).

The axiomatic foundation of classical western scientific methodology assumed the existence of universal laws, that could be mathematically characterised with the aid of experimental replication [111]. However, as Basarab Nicolescu [9] notes, human ontologies can include, but are not limited by mathematical characterisation. Thus, a transdisciplinary methodology cannot be used to approach the totality of human knowledge, if limited to the language of mathematics. In this connection, it is interesting to note that my tūpuna saw no need for a written numerical or symbolic language. It was the Christian missionaries who were responsible for systematising the oral traditions of my tūpuna as a written language, and this included the assumed relevance of a number system.[5]

6.4.2 The Ontological Axiom of Transdisciplinarity (Basarab Nicolescu)

> *There are, in Nature and in our knowledge of Nature, different levels of reality and, correspondingly, different levels of perception* [9, p. 9].

In Te Reo Māori (transl. the Māori language) there is no simple linguistic equivalent for the English word 'reality'. This is partly a consequence of differing worldview

[5] 'History of the Māori language', URL: https://nzhistory.govt.nz/culture/maori-language-week/history-of-the-maori-language, (Ministry for Culture and Heritage), updated 10-Oct-2017.

assumptions. My tūpuna did not employ exclusive logic to differentiate between living and non-living entities. Earth, sky and all of the entities of the natural world were members of whānau Māori (i.e. the Māori family ecosystem) and thus interdependently related by whakapapa (transl. genealogy). Thus, what western scientists call 'an experimental approach to reality' – was for my tūpuna (transl. Māori ancestors) – part of a ritualistic dialogue with family members. Despite this distinctly different ontology, the transdisciplinary axiom of 'levels of reality' that correspond to 'levels of human perception' seems to have been known by my tūpuna (transl. Māori ancestors).

First, my tūpuna (transl. Māori ancestors) employed pūrākau (transl. mythology, legend) to symbolically describe the highest level of intellectual attainment as 'Toi o ngā rangi' (transl. the summit or highest place of Ranginui our Sky father). The ascent to this summit of learning was first completed by one of the children of Papatūānuku (transl. our Earth mother) and Ranginui (Transl. our Sky father) named Tāne (trans. husband, male, man). To ascend to 'Toi o ngā rangi' (transl. the summit or highest place of Ranginui our Sky father), Tāne (trans. husband, male, man) had to climb his way through eleven levels of attainment, which each carry a distinctive name and meaning. This narrative, was to impress upon us that the expression of pūkengatanga (transl. the acquirement of specialist or expert skills and knowledge) involved a search for ever deeper levels of knowing [103]. These levels of knowing partly involve coming to terms with distinctly different Māori realities as symbolised by the 3 baskets of knowledge explained next.

Second, in Te Ao Māori (transl. all things in Māori worlds) discontinuities in space and time exist between different levels of knowing and reality. This understanding is symbolised by the meaning of 3 baskets of knowledge (transl. Ngā kete e toru) that were given to Tāne (trans. husband, male, man) when he reached 'Toi o ngā rangi' (transl. the summit or highest place of Ranginui our Sky father). These 3 baskets of knowledge (transl. Ngā kete e toru) contained all of the learning that my tūpuna would need to (i) maintain their collective survival and wellbeing and (ii) explore the deeper mysteries of the universe. The 3 baskets draw our attention to 3 different worlds (cf. levels of reality) that the late Rev. Māori Marsden [103] describes as the 3 worldview of the Māori. In other words, as Māori, we view the world (cf. reality) by simultaneously bringing together 3 completely different perceptions of reality, that correspond to 3 different worlds, that are symbolised by Ngā kete e toru (transl. the 3 baskets of knowledge).

In the first basket of knowledge – 'Tua-uri' (transl. beyond in the world of darkness) – there exists the "the real world of the complex series of rhythmical patterns of energy which operate behind this world of sense perception" [103, p. 60]. It is within the realm of Tua-uri that the evolution of the physical 'sensible world' emerges as a space-time framework [103].

The second basket of knowledge – Te Aronui (transl. as that before us) – corresponds to what the late Rev. Māori Marsden referred to as the "... world before our senses" [103, p. 61]. An important lesson from the 3 baskets of knowledge is that the world of sensory perception (what western scientists refer to as the macro-physical world) does not contain a complete explanation of causality. Much of what emerges in the sensory world is a direct result of flows of energy in the domain of Tua-uri (transl. beyond in the world of darkness). These energy flows find expression in Te Aronui (transl. the world of sensory perception), [103].

The name of the third basket of knowledge is Te Ao Tua-ātea (transl. the world beyond space and time). As the Rev. Māori Marsden explains:

> *Ātea is the word for space; it is usually combined with wā (time) to form wātea (space-time). They (our ancestors) saw space and time as conjoined together and relative to each other ... This is the eternal realm, which is before Tua-uri and towards which the universal process is tending. The worlds both of Tua-uri and Te Aronui are part of the cosmic process. And if the universe is process, it is more akin to life, mind and spirit, which are obviously processes. Therefore the world of sense perception, the natural world around us is unlikely to be ultimate reality. For the Maori, Tua-ātea, the transcendent eternal world of the spirit, is ultimate reality [103, p. 61–62].*

The 3 baskets of knowledge depict different worlds (cf. levels of reality) that our tūpuna used as a basis for enriched perception. I find it very interesting that only 3 baskets of knowledge are mentioned in the narrative that describes the knowledge that was given to Tāne (trans. husband, male, man) in 'Toi o ngā rangi' (transl. the summit or highest place of Ranginui our Sky father). Yet the late Rev. Māori Marsden draws our attention the existence of a fourth world.

> *To the three baskets containing the knowledge of the three worlds we must add a fourth world, the world of symbol. The world of symbol is a deliberate creation of the human mind. Man creates symbols to depict, represent and illustrate some other perceived reality. Words, formulae, forms, ritualistic ceremonies, legend and myth are created by the human mind as maps, models, prototypes and paradigms by which the mind can grasp, understand and reconcile the worlds of sense perception and the real world behind that [103, p. 62].*

The narrative of the 3 baskets of knowledge provides an interesting parallel to the 1^{st} axiom of Basarab Nicolescu (2005):

> *There are, in Nature and in our knowledge of Nature, different levels of reality and, correspondingly, different levels of perception [9, p. 9].*

The 3 baskets of knowledge could be thought of as differing levels of reality that collectively compose a cosmic process. The 4th world of symbols, corresponds to levels of human perception. The training needed to enhance different levels of Māori perception so that they could gain access to different levels of reality (cf. worlds) was the task of the Whare Wānanga (transl. a school of higher escoteric learning). While in the time of my tūpuna (transl. Māori ancestors), Māori knowledge was not organised around the contributions of different areas of (disciplinary) specialisation, mātauranga Māori (transl. Māori knowledge) was not entirely without structure. The escoteric schools of learning (i.e. Whare Wānanga) were staffed by tohunga (transl. experts, senior scholars) who took responsibility for different classes of knowledge and contributed towards growing it. Each tohunga was a gifted spiritual leader and possessed natural ability to communicate between the spiritual and temporal realms through karakia (transl. ritualistic dialogue), pātere (transl. ritualistic chants) and/or waiata (transl. lyrical narrative). The training of differing perceptive facilties is evidenced by the various offices of tohunga (transl. experts, senior scholars), whose abilities overlap in some areas, but were also aligned to differing baskets of knowledge (cf. levels of reality), [103].

Tua-uri (transl. beyond in the world of darkness) – the *tohunga karakia* specialised in rituals including the manipulation of mauri (transl. a pure form of energy responsible for bonding all things together). The *tohunga whakapapa* developed extensive knowledge of genealogy and thus understood the power of relationships in maintaining the whāriki (transl. fabric or weave) of Te Ao Māori (transl. all things in Māori worlds). It was the duty of the *tohunga whakapapa* to foster, maintain, and when necessary, repair relationships [36, 37, 103].

Te Aronui (transl. as that before us) – the survival and wellbeing of whānau Māori (transl. the Māori family ecosystem) in the world of sensory perception (transl. Te Aronui) involved the perceptive skills of the *tohunga whakairo* (transl. specialist in carving), the *tohunga tā moko* (transl. specialist in tattoo), the *tohunga kōkōrangi* (transl. specialist in astrology), the *tohunga tito waiata* (transl. specialist in lyrical narrative), the *tohunga tārai waka* (transl. specialist in canoe making) and the tohunga ahurewa (transl. ritual mediator), [36, 37, 103].

As my tūpuna (transl. Māori ancestors) used oral language and communication aids to transfer knowing across generations, they likewise applied symbolic subject-object-sacred skillfulness to everything they created. For example, whare (transl. buildings) and waka (transl. canoes) were carefully designed and constructed with remarkable artistic skill and carved adornment that made it possible to give visual expression within the world of human sensory perception (transl. Te Aronui) to the hidden worlds of Tua-uri (transl. beyond in the world of darkness) and Te Ao Tua-ātea (transl. the world beyond space and time).

Te Ao Tua-ātea (transl. the world beyond space and time) – the *tohunga ahurewa* (transl. ritual mediator) was a specialist in communication between worlds, in particular the various members of whānau Māori (transl. the Māori family ecosystem). This involved the acquirement of sacred knowledge, spiritual beliefs, customs and extensive knowledge of genealogy. As such, the tohunga ahurewa (transl. ritual mediator) was able to give advice about Māori community endeavours [36, 37, 103].

The existence of differing levels of reality and corresponding levels of perception in Te Ao Māori (transl. all things in Māori worlds) also resonates with a number of the theoretical postulates of Basarab Nicolescu [9].

First, in moving from one basket of knowledge to the next, there exists a discontinuity in logic and the space-time framework. So much so that it required evidence of giftedness and training by tohunga (transl. experts, senior scholars) to develop the perceptive skills needed to communicate and work within the worlds of Tua-uri (transl. beyond in the world of darkness) and Te Ao Tua-ātea (transl. the world beyond space and time). Beyond these specialist skills of the tohunga, daily activities in Māori communities were interdependently related with these 'worlds beyond' through the expression of kaupapa tuku iho (transl. inherited Māori values), the expression of tikanga (transl. right ways of doing things) and karakia (transl. ritual dialogue).

Daily activities within Te Aronui (transl. as that before us) – the world of sensory perception – also required the development of perceptive facilities related to daily interactions with Atua (transl. the children of Papatūānuku and Ranginui) who are the kaitiaki (transl. guardians, caretakers) of the various domains (cf. ecosystems) of this world of sensory perception. Development of sensory perception was possible by traversing the 12 levels of deeper learning symbolicly depicted in the journey of Tāne (trans. husband, male, man) to 'Toi o ngā rangi' (transl. the summit or highest place of Ranginui our Sky father). The following story from the Rev. Māori

Marsden about early fishing experiences nicely illustrates this point.

> *As children we often went fishing both in the harbour and in the open sea with members of the tribe. My father was always consulted. He would quickly calculate the day according to the Maori lunar calendar, the state of the tide, the direction of the wind and other phenomena. He would then advise us what reefs, or grounds to fish and the best times according to the state of the tide. He would advise against going to other grounds, which were handier or more popular as a waste of time. He would give us the reasons. By the time we were young men we had imbibed a lot of this traditional lore. Often we tested this knowledge and found it trustworthy* [103, p. 61].

Second, it is evident from this more escoteric knowledge provided in the writings of the late Rev. Māori Marsden, that no one position within these various worlds or levels of reality constituted a 'privileged place' from which to perceive the totality of all levels of this 3 worldview. Consistent with the postulates of Basarab Nicolecu, within this Māori conception of the world, a single level of reality exists, because all levels of reality co-exist at the same time. Thus, the notion of theoretical superiority appears to have been foreign to my tūpuna.

A distinguishing characteristic of Māori society, even today, after 170 years of the damaging effects of colonisation, is that quite different perceptions of the same reality 'co-exist' within Māori society and this phenomenum is not thought unusual. It is however, a cause of great confusion for western scientists who start dialogues with Māori communities while intuitively looking for 'superior explanations'. My t**ū**puna had a deep respect (cf. sacred regard) for Te Ao Māori (transl. all things in Māori worlds) and seemed to comprehend that there was little to be gained in arguing over the merits of one persons 'world' perceptions in relation to another's. Instead, they embraced all perceptions, and respected difference. This is especially evident when we consider the kaupapa and tikanga that guided 'collective' knowledge development [103, p. 35]. In this sense, Māori knowledge remains forever open. Consistent with what Basarab Nicolescu (2005) has postulated in regards to transdisciplinary knowing, the full depths of the 3 baskets of knowledge and the 12 levels of knowledge attainment will never be exhausted, nor confined to one self-enclosed theory.

6.4.3 The Logical Axiom of Transdisciplinarity (Basarab Nicolescu)

> *The passage from one level of reality to another is insured by the logic of the included middle* [9, p. 9].

In Te Reo Māori (transl. the Māori language) there is no linguistic analogue for the 'included middle'. However, it is equally clear to me that 'meaning' relating to the existence and critical importance of a 'T-state' or 'included middle' was not unfamilar to my tūpuna. I draw this conclusion from many lines of thought and experience including the following.

First, it is important to reiterate that the 'logic of the included middle' is a recent adaption of the 'classical western scientific logic' of the excluded middle, with its contradictory pairs: A and non-A. Exclusive logic forms the basis of all of the systems of categorical classification in western science, and the discretisation of a number system in mathematics. Dependence on the use of exclusive logic in western science has resulted in breath-taking analytical achievements. However, the western scientific world – beginning at the time of the quantum revolution – has had to come to terms with the fact that exclusive logic, while not wrong, is by itself an incomplete logic.

The limitations of the logic of the 'excluded middle' for achieving the goals of whānau Māori (transl. the Māori family ecosystem) survival and wellbeing appear to have been recognised by my tūpuna. My tūpuna (transl. Māori ancestors) saw a place for exclusive logic. This point can be illustrated by drawing attention to 'tapū' (transl. sacred) and 'noa' (transl. common) categories (cf. A and non-A) in Te Reo Māori (transl. the Māori language). However, by drawing attention to the existence of exclusive logic in Māori language, it is important to note, that the use of this logic does not effectively define or characterise the centre-of-gravity of 'logic' in Māori culture. While exclusive logic has been the dominant logic of classical western science, it is not the dominant logic of Māori culture. The 'inherited Māori universal values' of Māori culture (i.e kaupapa tuku iho) are dependent for their existence and expression on the use of inclusive logic. To use western scientific langauge, my tūpuna (transl, Māori ancestors) had a 'dual theory of logic' in which inclusive logic was the dominant logic of Māori culture.

Second, a moments reflection will lead to the realisation that the knowledge development goals of my tūpuna (i.e. the survival and wellbeing of the Māori family ecosystem) could not be achieved without inclusive logic. This is because, survival and wellbeing goals are systemic and holistic in nature, in a way that was needed to protect – the integrity of what anthropologists refer to as the human≡ecosystem identity relationship – *that is the central pillar of the Māori family ecosystem concept.* My tūpuna (transl. Māori ancestors) used their '3–world' island ecosystem home to co-create and co-adapt kaupapa (transl. inherited Māori universal values) in a way that made possible the simultaneous achievement of both human and ecological survival for approximately 800-1,000 years.

Finally, the role of 'knowledge co-creation' in Māori survival and wellbeing provides a fascinating insight into the awareness of my tūpuna (transl. Māori ancestors) of the importance of an 'included middle'. It it difficult to characterise Māori cultural knowledge co-creation processes from the perspective of scientific method *a priori.* This is because Māori knowledge creation processes are 'open' and 'socially mediated'. In other words, both the problem to be solved (collectively) and the means by which a problem is to be solved (i.e. what western scientists refer to as 'method') are generally unknown at the beginning of a collective, Māori knowledge development process. The success of a socially mediated knowledge development process of this kind is dependent on 2 critical factors.

First, the members of a Māori community ensure that the collective resolution of a problem, or the co-creation of knowledge is guided by the expression of kaupapa tuku iho (i.e. inherited Māori values). The expression of kaupapa tuku iho (i.e. inherited Māori values) as tikanga (transl. right ways of doing things) should not be confused with the application of 'methods' or 'processes'. In a socially mediated dialogue, that can appear random and directionless at times, the behavioural expression of Māori cultural values occurs in real-time. Thus, the concept of a *a priori* method is not helpful in describing or understanding this phenomenon.

Second, the fact that differing perceptions of the same reality are allowed to co-exist in Māori culture, provides a rich source of human perceptual access to differing levels of reality that can, in turn, be used to co-create and in some cases collectively stumble across previously unseen T–states (i.e. what Basarab Nicolescu (2005) refers to as the included middle). In this way, Māori knowledge co-creation is able to open and connect streams of consiousness between neighbouring levels of reality and human perception, in ways that resolve the logical contradictions that are a consequence of human perception based solely on the use of exclusive logic *at one level of reality*. Again, exclusive logic is not wrong, but it can only ever provide incomplete human perceptions of reality. This is because exclusive logic is, by its very nature, *intolerant of inclusion*.

In Māori culture, co-creation of knowing through the logic of the included middle is also beautifully illustrated in the meaning of the word 'ako' (transl. to learn, study, instruct, teach, advise). The Māori word used for 'learning' can also be used to refer to instructing, teaching or advising. Both exclusive and inclusive logics co-exist in the same word to describe a model of education in which 'student (A) and teacher (non-A)' can simultaneously be teacher (A) and student (non-A). This reconciliation of what are considered to be mutually exclusive A (i.e. student) and non-A (i.e. teacher) categories in western education is achieved through recognition of the fact that both student and teacher have epistemic access to different levels of reality and perception. Thus, their collective perceptions can be used to co-create knowing based on the mutually interdependent expression of Māori cultural values.

6.4.4 The Complexity Axiom of Transdisciplinarity (Basarab Nicolescu)

> *The structure of the totality of levels of reality or perception is a complex structure: every level is what it is because all the levels exist at the same time* [9, p. 9].

Co-creation of knowing, a 3 worldview, recognition of the existence of differing levels of perception and reality, along with the adoption of a dual theory of logic means that the knowledge development activities of my tūpuna (transl. Māori ancestors) also contributed towards a certain Māori cultural knowing of complexity. Western scientific notions of complexity are not easy to translate using the vocab of Te Reo Māori (transl. the Māori language) and this includes the complexity categories postulated by Basarab Nicolescu (2005), (i.e. horizontal, vertical and transversal). However, a Māori knowing of complexity exists and can be approached by focusing attention on differing aspects of Māori 'culture' as explained below.

> *In Maori terms then, culture is that complex whole of beliefs, attitudes, values, mores, customs, knowledge acquired, evolved and transmitted by his society as guiding principles by which its members might respond to the needs and demands dictated by life and their environment* [103, p. 34].

First, the expression 'Te Ao Māori' (transl. all things in Māori worlds) draws attention to Māori cultural complexity (i.e. all that is included in the 3 Māori worlds). A distinguishing characteristic of this Māori notion of 'complexity' is that it is based in Māori cultural (i) systems of *belief, attitudes, values, mores, customs, knowledge acquired, evolved and transmitted* as a basis for responding (ii) to *the needs and demands dictated by life and their environment.* Thus from a Māori perspective, the human perception of reality – what the late Rev. Māori Marsden refers to as the world of symbols (i.e. belief, attitudes, values, mores, customs) – is a constituent part of 'all things Māori' (i.e. complexity). This conception of Māori complexity is consistent with the vertical complexity category of Basarab Nicolescu (2005).

Second, as noted earlier, a Māori cultural model of complexity, in western scientific terms, does not isolate the 'subject', 'object' and 'sacred'. Furthermore, what western scientists refer to as the 'scientific subject', in Māori cultural terms, would not be considered as an individual observer. Instead, the Māori 'subject' symbolises a collective that uses the creative power of the 'included middle' to fashion new knowing that is, irreducible, in terms of its relationship to pre-existing knowing. Furthermore, dependence on an oral language to store and transfer subject–object–sacred knowing across time ensured that the mana (transl. status) and integrity of subject-object-sacred knowing (cf. complexity) was maintained from one generation to the next. Subject-object-sacred knowing corresponds to the horizontal and vertical complexity categories of Basarab Nicolescu (2005).

Third, it is not possible to explore a Māori conception of complexity without making mention of whakapapa (transl. genealogy, genealogical table, lineage, descent). Whakapapa (transl. genealogy, genealogical table, lineage, descent), would have to be the ultimate symbolic representation of Māori cultural complexity that traces our genealogy back to Papatūānuku (transl. our Earth mother), Ranginui (transl. our Sky father) and Atua Māori (transl. the children of Papatūānuku and Ranginui) in a way that includes associated features, plants and animals of the natural world. Whakapapa (Transl. genealogy, genealogical table, lineage, descent) provides a powerful symbollic representation of the temporal and organisational complexity of whānau Māori (transl. the Māori family ecosystem) that was used extensively in Māori society to establish lineage (as a claim to leadership), land, fishing rights and status [36, 37]. It was also used by kaitiaki (transl. guardians, caretakers) to monitor the development and wellbeing of whānau Māori (transl. the Māori family ecosystem). Whakapapa thus partly corresponds to the transversal complexity category of Basarab Nicolescu (2005).

Fourth, oral language and vocabulary (cf. ontology) also support a Māori cultural conception of complexity. The importance of this relationship cannot be over-stated. Dependence on exclusive logic has had a dramatic affect on the English language. According to online sources[6], there are now in excess of 1 million words in the English language and this includes the entire specialist vocab libraries associated with western scientific disciplinary specialisations. By contrast, the core vocabulary of the Māori language is approximately 600 words. This does not include the existence of English loan words and transliterations. The evolution of language based on exclusive logic can only lead to ever increasing levels of disaggregation (cf. specialisation) in academic disciplines and the English language itself. By contrast, the dominant use of inclusive logic in Te Reo Māori (transl. the Māori language) resulted in the aggregation of meaning into a comparatively small, core, and multivalent vocabulary. Why didn't our tūpuna invent thousands of new core vocab constructs to assist them in accurately describing their complex cultural perceptions of reality?

The answer to this question lies partly in the central role of inclusive logic in Māori culture and the fact that the goal of unifying knowledge is also important to Māori communities. Mātauranga Māori (transl. the corpus of Māori knowledge) is unified in a way that is not inconsistent with the existence of vertical complexity

[6] 'No. of words in the English language', https://www.languagemonitor.com/. According to the online language monitor, the English language passed the 1 million word threshold on the 10th of June, 2009 at 10.22am (GMT)

(the co-existence of differing human perception of reality). This knowledge unification goal could be achieved because 'explanatory superiority' was not the central objective of Māori knowledge creation. It was instead, the emergence of perceptual creativity, māramatanga (transl. enlightenment) and mōhiotanga (transl. experiential knowing) through the logic of a Māori included middle.

Finally, the goal of Māori knowledge unification can be illustrated by drawing attention to an interesting characteristic of the co-creation of knowledge in what I have suggested is a Māori 'included middle'. While involved in co-creating knowing, how do the members of a Māori community collectively 'know' that a 'T–state' has been discovered? The answer to this question is that the presence of wairua (transl. the spirit of a person that exists beyond death) becomes evident in the form of collective 'resonance' or 'agreement'. Wairuatanga (transl. a collective experience in wairua) involves a 'collective knowing' that is beyond disciplinarity. I draw attention to this phenomenon, partly because of the derivation of the word 'wairua' – wai (transl. water) and rua (transl. two) as literally 'two waters'. Thus, in Māori cultural terms, the 'included middle' is a meeting place of 2 sacred waters (i.e. the sacred waters that flow from levels of reality and the sacred waters that flow from levels of human perception). The meeting of these sacred waters creates 'resonance'. This insight also draws attention to the fact that a Māori cultural experience of the included middle is necessarily based on the simultaneous perception of the 3 worldview of the M**ā**ori [39].

6.5 Concluding Comments

This chapter draws on key characteristics of New Zealand Māori cultural experiences in knowledge development to define what I describe in English as an indigenous (M**ā**ori) transdisciplinarity. There are a number of points, worthy of mention that follow from this chapter. First, there has been a tendency on the part of western scientists to view cultural contributions to knowledge development as 'non-science' (i.e. non-A). While this classification is technically correct, in terms of the use of the logic of the excluded middle (i.e. A and non-A), it is both wrong and unhelpful to draw from this categorisation the conclusion that culture has no legitimate or valid role to play in knowledge development. As I have attempted to show in this chapter, the survival and wellbeing of the human family on planet Earth is ultimately a problem of cultural survival and wellbeing. It is none-other than the world's 6,900 cultures that are best qualified to solve their *own* cultural problems. Culturally mediated human knowledge development is thus crucial to human cultural survival and wellbeing.

Second, it is equally unhelpful to hold the view that western scientific knowledge, methodology and methods have in some way superceeded or surpassed the knowledge development traditions of the world's cultures and in particular the world's indigenous cultures. This conclusion is both irrelevant (because it is lacks valid evaluation criteria) and in the case of New Zealand Māori, factually incorrect. What I have attempted to show in this chapter is that at the time of first arrival of Captian James Cook in New Zealand, in 1769, the knowledge development activities of my tūpuna were at least 216 years ahead of comparative theoretical and methodological developments in western science [i.e. 112].

Third, the knowledge development traditions of my tūpuna (transl. Māori ancestors) sustained whānau Māori (transl. the Māori family ecosystem) on this island archipelago for approximately 800-1,000 years. In New Zealand at least, this is the only 'time proven' model of human and ecological sustainability that we currently have. By comparison, the introduction and eventual dominance of a western model of science and market economy has led to a rapid decline in the wellbeing of whānau Māori (transl. the Māori family ecosystem) – *in some cases to critical threshold values – in other cases to the point of extinction.*

For a small country, with a relatively small population, our ecological performance over the last 170 years in terms of species extinctions, deforestation, the destruction of wetlands, overharvesting of marine ecosystems, the pollution of inland waterways and the destruction of Māori communities is nothing to boast about. A very real challenge facing Māori communities today is the realisation that whatever western science and the market economy had to offer, they have so far not demonstrated the ability to maintain the survival and wellbeing of whānau Māori (transl. the Māori family ecosystem). The decolonisation of western science that started in the late 1990s has provided a partial remedy to this problem. However, attention must now be turned to the decolonisation of capitalism and the market economy, as a Māori cultural (cf. indigenous) imperative for achieving the (now) future goal of cultural survival and wellbeing.

Fourth, this chapter provides an initial attempt to characterise and theoretically position the knowledge development activities of Māori scholars and communities in relation to mode–1 (disciplinary science), mode–2 transdisciplinarity (i.e. the Zurich model) and strong transdisciplinarity (i.e. the transdisciplinary methodology of Basarab Nicolescu 2005). In New Zealand, an ongoing struggle with the Government, large businesses, universities and research institutions for recognition of the legitimacy of Māori contributions to knowledge development is set to continue for some time to come. However, an opportunity now exists for emerging transdisciplinary scholars to think carefully about the methodological development and practice of transdisciplinarity in order to avoid what I have described in this chapter as another wave of colonisation for the world's indigenous peoples. In particular, the use of transdisciplinarity in cross-cultural endeavor is a skill that must be learnt – the same as any research method – and ideally should be combined with the development of competency in the language of those so-called 'non-scientific' communities that participate in cross or trans-cultural research endeavours. There is also an urgent need for transdisciplinary scholars to engage in emerging decolonising literatures.

Finally, I have noted in this chapter that in order to survive, the members of a cultural group require the freedom to give daily expression to their distinctive language, values and cultural institutions within functioning cultural ecosystems, landscapes and nation states. Culturally-mediated efforts to create knowledge as a basis for survival requires recognition, encouragement and financial support from world governments and corporate entities. If, as a global community we are unable to provide conditions and support of this kind, if we are unable to recognise the past, present and future value of culture, then over the next 100 years we currently stand to loose somewhere between 50-90% of our current linguistic and cultural diversity [12]. Thus, given the findings of this chapter, it seems appropriate to make a plea that we can please make room for an indigenous transdiscplinarity in the western academy.

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About the Author

Anthony Cole: Tainui is my canoe. Tararua is my mountain. Ōtaki is my river. Ngāti koroki is my hapū (transl. extended family). Ngāti Raukawa ki te Tonga is my iwi (transl. an extended kin group). Anthony is my name and I am a descendent of the Māori peoples who travelled the South Pacific ocean in canoes and settled in Aotearoa (transl. New Zealand) approximately 1000 years ago. While I was trained in the western academy, I work primarily in a Māori community context with a focus on Māori cultural survival and wellbeing.

CHAPTER 7

The history of the Indian sacred book (Atharva-Veda) and its contribution to the Integrative medicine model

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There are four Vedas (the Sacred books of Hinduism). The fourth, the Atharvaveda, cover several topics related with health sciences (diseases, their causes and cures, longevity, and so on), and so this Veda is considered to be a precursor of Ayurveda. This paper seeks to be a study of the contribution of the Ayurveda to the appearance of the Integrative medicine model (synthesis of Ayurveda with Western medicine).

Keywords*:* Indian Sacred books (Atharva-Veda), Ayurveda medicine, integrative medicine model.

7.1 Introduction

The Arian race brought to India the Vedas (the sacred books of Hinduism). The fourth Veda, the Atharva Veda, deals with some topics such as Bhaisajya (diseases, their causes and cures) and Ayusya (supplications for longevity). These have contributed to the appearance of the Ayurveda – the traditional Indian medicine.

The Ayurveda medicine, sometimes called by mind-body medicine [1], argues that the root of some diseases is due to an imbalance of the mind (our personal thoughts and/or feelings) which means that the cure have to be performed by the mind itself and not only through allopathic medicines, surgery and energy radiation, as recommended by conventional medicine (Western medicine). A fundamental component of the Ayurveda medicine (and Eastern medicine) is regeneration and recovery of wholeness (etymologically, “healing” and “whole” come from the same root). The base of this thinking is described in the Vedas that refer to the Theory of Reincarnation (several cycles of birth until the Law of Cause and Effect of Consciousness or “karma” is balanced [2]) as a way for the evolution of the consciousness of the patient, that is, "alignment" of soul, mind and body. This idea supports an

Integrative medicine model (synthesis of Eastern and Western medicine), as argued by several physicians in the contemporary society.

7.2 The History of Indian Medical Book (Atharva-Veda) and its Relationship with Ayurveda

The Hinduism has many sacred books, such as the Vedas and Upanishads [3]. The Vedas [4] are considered to be an "apaureseya" because the sages who have written them are anonymous. Furthermore, this kind of religious literature is named by "sruti" ("what is heard from God"). Thus, the Vedas are considered to be Divine revelations to sages [5]. There are four Vedas: Rigveda, Yajurveda, Samaveda and Atharvaveda. Each Veda has been classified into four types of text [6], namely Samhitas (mantras and benedictions), Aranyakas (texts on rituals), Brahmanas (ceremonies and sacrifices) and Upanishads (texts on meditation, philosophy and spiritual knowledge).

The Atharvaveda (from Sanscrit Atharvavanas (Atharva) and Knowledge (Veda)) [7] was composed in Sanskrit and it is a collection of 730 hymns with about 6000 mantras and divided into 20 books. These books were arranged by the length of the hymns (each one with a similar number of verses) [8]. The Atharvaveda is sometimes called the "Veda of magical formulas" because is considered to be able to remove illness through magic-religious rituals and some homemade medicines. In this regard, I have to mention that Atharvaveda is one of the oldest texts on the "earliest forms of folk healing of Indo-European antiquity" [9]. Furthermore, the Atharvaveda had nine schools, but only two of them have come to current day: the Paippalada and the Saunakiya [10].

The hymns of Atharvaveda cover eight topics, namely Bhaisajya (diseases, their causes and cures), Ayusya (supplications for longevity), Paustika (welfare), Abhicarika (spiritual progress), Prayascitta (expiatory rites), Rajakarma (political system) and Brahmanya (nature of Brahman or God). In this paper, I will do just the description of Bhaisajya suktas and Ayusya suktas because they deal with the connection between Atharvaveda and Ayurveda. The Bhaisajya suktas deals with the theme of the health sciences and for this reason is considered to be the precursor of Ayurveda (from Sanscrit Life (Ayur) and Science (Veda)). These suktas contain many prayers to cure diseases, such as fever, leprosy, diabetes, tuberculosis, skin disorders, diseases of the ears, nose and throat and some heart troubles. In this regard, the names of several parts of the human body (anatomy) are referred to Bhaisajya suktas. Furthermore, these suktas claim that some diseases are caused by violation of the Laws of nature or sins committed by the patient. The Ayusya suktas contain contains general requests for longevity and particular demands related to religious life. For example, the caula (tonsure), upanayama (investiture with the sacred thread), raksasutra (tread of protection).

The first seven books of Atharvaveda [11] refers to magic poems to cure some sorts of diseases, while books eight to twelve deal with several topics about healing. The books thirteen to eighteen describe some rituals of human life [12]. For example, the verses in hymn 4.15 of the Paippalada of the Atharvaveda, discuss how to deal with a fracture [13], while the verses in hymn 5.21 of Paippalada of the Atharvaveda claim that some diseases, such as fever [14], are caused by evil spirits who enter into the patient's body in order to cause disease. In other words, this means that the behavior of the person (the character) influences on personal health and well-being. Furthermore, some other hymns in the Atharvaveda deal with some medicinal plants and herbs that have been applied in Ayurveda.

The Atharvaveda Samhita [15] includes also some others hymns, such as 4.1, 10.7 and 17.1, that deal with metaphysical topics on the nature of existence of mankind. For example, the hymn 10.7 of Atharvaveda defends that the "source of Cosmic order is Brahman". Furthermore, some hymns of the Atharvaveda, such as 7.52, also claims that spiritual evolution and healthy life are related between them. The Atharvaveda has no Aranyaka, while the Brahmana is related with the Samhita. Furthermore, the Atharvaveda has three Upanishads, namely Mundaka, Manduka and Prashna [16], [17].

The Mundaka is written in form of mantras that are used to teach and meditate on spiritual matters. The Mundaka is constituted by three parts. The first part deals with the distinction between the science of "Higher knowledge" (that describe the spiritual Laws) and the science of "Lower knowledge" (that deal with the natural Laws), arguing that only through the knowledge of God, the human being can minimize suffering. Thus, the second part refers to Brahman and Atman (the Soul), while the third part describes the practical behavior that needs to be cultivated by the human being in order to experience Paramatman (God). For example, Satya (reliable), Tapas (perseverance), Samyajnana (wisdom) and Brahmacharya (celibate or balanced sentimental life). The Manduka discusses the meaning of the sacred word OM and relate it with the philosophical theory of "states of consciousness" which is presented in Hinduism and Buddhism. The Prashna contains some metaphysical questions that are answered through philosophy, mythology and symbolism.

In historical terms, over the last years, the Atharvaveda has been less studied than the other Vedas. Most positively, some researchers, such as Whitney [18], have made several translations and studies on the Atharvaveda. Furthermore, Bloomfield [19] has highlighted the importance of the study of Atharvaveda in the Vedic tradition. Following Whitney's and Blommfield's efforts, Bhattacharya [20] has announced the discovery of several manuscripts of the Paippalada Samhita. In this regard, recently several books of the Paippalada Samhita were translated and edited [21].

On the other hand, the roots of Ayurveda [22] are also in Hindu texts named by Charaka Samhita (an internal medicine treatise) and Sushruta Samhita (a surgery treatise). In this regard, I have to mention that both of them claim allegiance and inspiration on Atharvaveda [23]. For example, the Rishi Sushruta (who made several contributions to surgical practice) referred to the Atharvaveda as a book of "reference" for medical practice [24], being this opinion also supported by Charaka Samhita [25] in the verse 30.21.

The Charaka Samhita [26] consists of eight books, namely the Sutra Sthana (General principles on medical definitions, prevention of health through a balanced life), Nidana Sthana (Pathology on causes of diseases), Vimana Sthana (Specific advices about ethics in medical practice, diet and nourishment of the patient), Sarira Sthana (Anatomy of the human body), Indriya Sthana (Diagnosis based on sensorial response of the patient), Cikitsa Sthana (Therapeutics on treatment of diseases), Kalpa Sthana (Pharmaceutic and toxicology about the preparation of medicines) and Siddhi Sthana (ways to increase success in healing treatment).

The Sushruta Samhita [27] is divided into two parts. The first is constituted by five chapters (Sutra-sthana, Nidana-sthana, Sarira-sthana, Cikitsa-sthana, Kalpa-sthana), while the second (Uttara-tantra) was added by Dridhabala. The content of these two parts deals with several topics on medical practice.

7.3 The Contribution of Ayurveda to Integrative Medicine

The Ayurveda [28] (and Eastern medicine) claims that some medical signs are required in order to make a proper diagnosis of the patient. The relationship of mind and body in the human being is performed by the physician of Ayurveda through the "doshas"(vata, pitta and kapha) [29]. For example, a person with an anxious mind (in Ayurveda is designated by "rajas") might have a nervous breakdown, while a person with a lazy mind (in Ayurveda is designated by "tamas") might have a depression. In the same way, in Western medical books (from conventional medicine) four mind humours are considered to be important in order to make a proper medical diagnosis, namely the choleric, the phlegmatic, the melancholic and the sanguine. In this regard, I have to mention that the choleric humour corresponds to Ayurvedic pitta type; the phlegmatic humour corresponds to Ayurvedic kapha type; the melancholic and the sanguine humours correspond to Ayurvedic vata type [30].

The Ayurveda also claims that some diseases only might be cured (such as, lung cancer) through the change of behaviour and the "state of consciousness" of the patient (such as, give up smoking) [31], [32]. In this regard, Ayurveda defends that the human being might experience several levels of perception or reality [33] – manifested in the chakras [34] - according to the personal behaviour. The Eastern medicine also defends that the vital energy of the human body (called by "prana") flows in pathways called by "nadis". Furthermore, the vital body (constituted by the several "nadis") is connected with the physical body in the chakras. Thus, the relationship between vital and the physical bodies might contribute to the connection of the Ayurveda with the Western medicine [35]. For example, if a patient "block" movements of vital energy (due to stress or fear), this might contribute to the appearance of cancer [36]. Recently, it has been suggested some Integrative medicine models (synthesis of Ayurveda and Western medicine) to health care systems that might contribute to cure the patient in an holistic way (body, mind and soul) as defended by the Atharvaveda [37]. One of the advantages of an Integrative medicine model is to find a "rational" explanation of distant and spontaneous cures [38], [39] as well as, the healing of "incurable" diseases which are described in the Indian Sacred books [40]. In this regard, I have to mention an experiment carried out at San Francisco hospital by Byrd [41], where were made prayers (in a random mode) to a group of patients (without the patient's knowledge) for the recovery of the disease. The result was that patients who have had prayers at a distance recovered more quickly. Thus, the prayer has an effect on the cure of the patient, as defended by the Indian sacred books, referred to earlier.

7.4 Conclusions

The diagnosis and treatment performed by Western medicine (conventional medicine) focuses exclusively on the physical and biological aspects of the patient. However, the human being has also an emotional, mental and spiritual dimension that need to be taken into account for a full and holistic diagnosis and treatment of the patient

[42]. In this regard, the Indian Sacred books, particularly the Atharvaveda (the precursor of the Ayurveda), claim that self-healing [43] depends on a process of self-awareness and spiritual evolution of the human being. Furthermore, the main target of an Integrative medicine model (an evolutionary model of healing) [44] is to cure all dimensions of the human being, as well as to explain in a scientific way the relationship between the health of the patient and the personal spiritual evolution of the human being, as described by the Sacred books of all religious traditions (Vedas, Bible, Qur' an, Torah).

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CHAPTER 8

An Essay Concerning Human Decisions

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Based on decades of combined experience in teaching, observing and working with decision makers, we realized that the praxis of decision making as well as our own approach has always been transdisciplinary. Therefore in this paper we offer a transdisciplinary model of decision making at three levels of reality, namely model, method and tool. We conduct our inquiry in the realm of human-social studies, and argue that in this realm we need to transcend the traditional hard sciences and include a soft approach. Along the way we examine the concept of transdisciplinarity within human-social studies, and introduce the concept of meta-knowledge. Examining the research and teaching of decision making on this basis, we suggest that 'coffeehouse philosophers' should teach about decision making, bringing in practicing decision makers whom they interview, while students will need to go through a process of 'bootstrap learning' figuring out their decision problems.

Keywords*:* Decision making, transdisciplinarity, meta-knowledge.

8.1 Introduction

> *" If the human brain were so simple that we could understand it, we would be so simple that we couldn't."*
>
> **Emerson M. Pugh**[1]

Paraphrasing John Locke's [1] book title, in this essay we speculate about how people make decisions. We, the authors of this essay, have been teaching about decisions for several decades, primarily in business schools, but also as guest teachers in medical, sport, engineering, psychology, and law schools. This essay is a personal

[1] Quoted in 'The Biological Origin of Human Values' by George Edgin Pugh (1977). Author's note: Quote from my father around 1938. Biologist Lyall Watson, described it as "the Catch-22 of the biology of consciousness."

take on the way we perceive decisions and teach about decision making, as well as how we realized, with hindsight, that our approach has always been transdisciplinary. However, this is not only a 'l'art pour l'art' musings on decisions – although it started as such. We view this essay as a nuanced conceptual starting point, necessary for a future empirical study.

When talking about decisions we implicitly talk about thinking, and therefore knowledge. More precisely, we are interested in fast (intuitive) decisions [2], and the knowledge required for it. We base our conceptualization of knowledge on Polányi's notions of 'personal knowledge' [3] and 'tacit knowing' [4]. Instead of engaging with the scholarly endeavors since Polányi's foundational work, we go back to the original work in which we build our approach directly. From this basis, we explore the scientific approach to knowledge, and argue that if we want to achieve a rich picture of knowledge, we need a more open approach than that which the dogmatic view of positivist science would allow. A proper scientific account of knowledge must be to some extent unscientific.

The reason for this is the following: Ignoring tacit knowledge leads to such a limited view that it loses touch with reality. In turn, tacit knowledge cannot be meaningfully examined within a purely positivist framework. As a mathematician friend of ours, who works in psychology, said: 'No one who attempts to analyze the unconscious has actually understood it.' In essence, if it could be analyzed, it would not be unconscious. Paraphrasing this maxim, our starting assertion is that tacit knowing cannot be analyzed. In positivist science, analyzing means taking apart, modelling in the algorithmic sense, and describing as a well-structured process, which cannot be done with tacit knowledge. This does not mean, however, that we cannot theorize about the nature of tacit knowing, examine the purpose for which it can be useful, when, and particularly whose tacit knowing to trust.

As with any discussion on the topic of tacit knowledge, our argument in this essay is also somewhat unscientific. The reason is that we want to bring together several highly complex concepts, and we believe that aiming for the intuitive understanding of the readers, using a personal account, is more fruitful than listing who said what. And we believe that "[t]oo many definitions kill rigor, which is why poetic knowledge is more rigorous than scientific knowledge" [5]. Therefore we do not offer a traditional literature review, covering a historical overview of the significant milestones of the scholarly decision literature [e.g. 6; 7; 8; 9; 10; 11; 12; 13; 14] and a review of what can be considered up-to-date [such as 15; 16; 17; 18]. Instead, here we offer a picture based on our personal histories, which is necessarily subjective and partial. Similarly to the way mathematicians often elaborate several lemmas that are subsequently brought together in the main argument, we take a triple detour following the initial exploration of the concept of knowledge. In the first detour, we elaborate a view according to which it is an imperative to include the 'soft side'. In the second detour, we use the example of Einstein, as reported by Polányi, to demonstrate the necessity of what we call meta-knowledge. In the third detour, we introduce our view of transdisciplinarity. Finally, we bring these three approaches together to elaborate our new model of decision making. In our concluding remarks, we present our personal view of decisions and of teaching about decisions.

8.2 A Philosophical Detour: Towards a Soft Approach

We start with a personal example of a chain of master-apprentice relationships [3; 19; 20]. Zoltán Baracskai (the first named author) started his journey as a scholar in 1979, when his master told him to read Polányi's book 'Personal Knowledge'. Zoltán then gave the same book to Viktor Dörfler (the second named author), Viktor to his apprentice who then gave it to his apprentice. We don't want to suggest that Zoltán's master and the apprentice of Viktor's apprentice made the same sense of Polányi's work. However, all of us realized that it makes no sense trying to dissect tacit knowledge, trying to find its constituents, or model it. In this essay tacit knowledge is the fixed point, using which, in Archimedes' words, we try to move the world – i.e. to understand decision making better.

We studied the philosophy of science with Kuhn [21; 22], Popper [23; 24] and Feyerabend [25; 26], and will continue studying such esteemed thinkers. However, their works were of limited help, as we dedicated our lives, as scholars, to the research within the soft scope, namely within the human-social studies, while the major works in philosophy of science refer to the hard sciences. The concept of science (scientific knowledge) is controversial, as it is impossible to divorce scientific knowledge from other forms of knowledge. Why? Because, according to Polányi's famous dictum, all knowledge is rooted in the tacit dimension:

> *While tacit knowledge can be possessed by itself, explicit knowledge must rely on being tacitly understood and applied. Hence all knowledge is either tacit or rooted in tacit knowledge. A wholly explicit knowledge is unthinkable.* [27]

Dogmatic scientists sometimes argue that only positivist science qualifies as science, basing their argument on the use of they refer to as the 'scientific method'. And, as Heisenberg says:

> *Confidence in the scientific method and in rational thinking replaced all other safeguards of the human mind.* [28]

However, even the hardest of sciences, physics, cannot be fully locked into the positivist box anymore. To talk about knowledge in the strictly positivist framework, we would need to derive a conceptualization of knowledge from matter, as in a strictly positivist science everything has to be derived from matter. As Schrödinger warns us, with reference to consciousness:

> *All this is pure fantasy, as irrefutable as it is unprovable, and thus of no value for knowledge.* [29]

Physics actually seems to be doing somewhat better than the human and social studies in abandoning some obsolete requirements of the scientific enterprise. There have been numerous physicists recently (e.g. Geoffrey Chew, David Bohm, Robert B. Laughlin) transgressing the positivist boundaries in an attempt to broaden their horizons. Scholars in the human-social studies far too often try to copy an obsolete world of physics; this is the essence of what von Hayek [30; 31; 32] refers to as 'scientism'. While we do not intend to offer a different demarcation or classification between science and non-science here, we suggest that a non-positivist or even anti-positivist perspective needs to be included in studying decision making. To represent this 'other side', we bring in Bourdieu's [33] sociological approach.

Umberto Eco pictures scientists becoming, like monks in a monastery, isolated from the 'real world', occasionally maybe visiting it, but living and working separately from it. Bourdieu [33] explains this through the mathematization of science, which helped hard sciences, and particularly physics, in gradually achieving considerable autonomy, but at the same time, being a mathematician became an entry-barrier to science, drawing a line between professionals and amateurs, and then between insiders and outsiders. Unfortunately, this also led to a severe reduction of the readership, as reading science books or papers started to mean reading equations: after a while, only insiders were able to read what other insiders wrote. In the soft knowledge domains in general and in decision making in particular, a similar tendency can be observed and we believe that this can lead to catastrophic consequences; what Cathy O'Neil[2] calls 'weapons of math destruction' in her TED Talk.

In hard sciences, a lot can be achieved looking at the world from the outside. When designing a machine, we do not need to become cogs in order to understand how the machine works. To understand atomic interactions we do not need to become quarks. In the human-social studies, we cannot avoid being humans nor being social. If we separate ourselves from the world of humans, lock ourselves into a monastery, we cannot understand that world. This, however, leads to an interesting and very tricky situation in teaching. For example, should practicing decision makers teach about decision making? No, they shouldn't, as they cannot teach (there may be exceptions but those are rare). Should we therefore get the highest ranked academics (assuming that they are excellent teachers) to teach about decision making? There is also a serious limitation to this; in pursuing such academic careers, academics then remove themselves from the praxis of decision making. They can teach, but they cannot reflect on the praxis as they are not part of it. So who should teach about decision making and how? We are searching for an answer to this question for several decades, and this paradox drives out exploration in this paper.

The Universal Truth, the ideal of fully objective science[3], is not an external entity that we are approaching, but a complex system of partial and subjective truths. We do not need to give up our subjectivity trying to be governed by an externally given objective truth, but we need to embrace our subjectivity and pursue it, in order to create a universal truth that emerges from the synergistic assembly of all which is partial and subjective. We could even say that this is our interpretation of Popper's [23] conceptualization of inter-subjectivity, which he offers as a replacement for the notion of objectivity. This is hard enough to do in the hard sciences, but in the human-social studies it is many times harder. The reason is that any human-social inquiry needs to make itself also part of its own inquiry [cf 33]. And this is also the point where, for the first time since antiquity, human-social studies can advance beyond the hard sciences and become the example that the hard sciences may follow. This is why we could say with reference to hard sciences that it is not exactly true that we do not need to become cogs and quarks. Heisenberg recognized that "in the drama of existence we are ourselves both players and spectators". Although hard sciences can still progress without accepting this, their pursuit of science will come to halt, and they will need to accept it eventually. It is up to us in the human-social

[2] https://www.ted.com/talks/cathy_o_neil_the_era_of_blind_faith_in_big_data_must_end

[3] Our assertion only applies to the idea of the objective Universal Truth in science; the idea of spiritual Universal Truth is outwith the scope of this inquiry.

studies to do the pioneering work, as we cannot progress if we detach ourselves from our subject of inquiry, as that would mean detaching ourselves from ourselves.

8.3 A Methodological Detour: Meta-Knowledge-Approach

We start with a story of the experimental implications of Einstein's theory of relativity, and Polányi's [34] analysis of this remarkable case of Einstein's intuition. The particular experiment in case is the Michelson-Morley experiment that established that a light source would never overtake a beam sent out by it. Importantly, the Michelson-Morley experiment was conducted earlier than Einstein developed his conceptualization of relativity. In his autobiography, Einstein offered an account according to which he intuitively recognized the nature of light. This was without being familiar with the experimental results of Michelson and Morley where Einstein made the same assumption from the start. It was assumed that Einstein must have known of the experiment and his conceptualization of relativity was the way of providing the conceptual framing for the experimental results. In contrast, Polányi argues that:

> *[...] when Einstein extended his vision to the universe and included the case of a light source emitting a beam, he could make sense of what he then faced only by seeing it in such a way that the beam was never overtaken, however slightly, by its source. This is what he meant by saying that he knew intuitively that this was in fact the case.* [34]

According to Polányi this vision led Einstein to the conceptualization of relativity, which does explain the Michelson-Morley experiment but, contradictory to the general belief, is not based on it. What we find in this story is what we tentatively label meta-knowledge. There is a small problem with this label: it may be read as 'knowledge about knowledge'. This is not what we mean here. What we refer to with the 'meta-' is a very high level of abstraction, something that we can call meta-level. At a high level of abstraction, where the details of reality dissolve, such knowledge loses direct touch with reality. However, it can be 'concretized' by zooming into reality, and in this 'concretization' the meta-knowledge can take radically different forms. For instance, it may take the form of some knowledge with reference to one reality and some different knowledge with reference to some other reality. For this reason, meta-knowledge does not consist of concepts but of meta-concepts, which are extremely high-density essences of many concepts. This is why we discussed great thinkers in the above examples: those who see the totality of their disciplines possess meta-knowledge and develop meta-concepts. Usually there are no words corresponding to meta-concepts, therefore the great thinkers often communicate their meta-knowledge in the form of metaphors, which is another reason to use the 'meta' label.

Meta-knowledge is heavily tacit. This meta-knowledge, and its tacit nature, is what enables the greatest thinkers to demonstrate sometimes almost supernatural abilities, which may at times present as "extra-sensory perception" or "acts of precognition or apparent clairvoyance" [35]. We would risk the assertion that every single great breakthrough in science has been achieved in this way, even when the story is not as striking as the one about Einstein.

Meta-knowledge, in contrast with low-level (i.e. closer to reality) well-structured concepts, cannot be directly transferred. If great thinkers teach, they will not attempt to transfer their meta-knowledge. They are the only ones who can apply their own meta-knowledge. Yet, through metaphors, and/or larger metaphoric narratives called parables, great thinkers can 'send' meta-concepts that the talented learners can 'receive', reinterpreting the meta-concepts their own way, and develop their own meta-knowledge. When learners receive a meta-concept from a discipline that is not their native discipline, they will not magically become 'masters' of the new discipline, but they will be able to grasp some of its essence. Talented learners can use the deep insight embedded in the meta-knowledge to enrich their own knowledge of their own discipline.

We can learn one further thing about the nature of meta-knowledge from Einstein's story. Intuitively apprehending the experimental facts, from which he had no prior knowledge, was not possible whilst remaining within the discipline of physics; Einstein had to transcend the disciplinary boundaries. We use this as an illustration, as a justification but not a verification, that the disciplinary boundaries must be transcended for the highest achievements. This led us to consider Nicolescu's conceptualization of transdisciplinarity.

8.4 A Conceptual Detour: Towards a Transdisciplinary Approach

We know that the initial framing of transdisciplinarity can be traced back to Piaget [36], but it was Nicolescu [e.g. 37] who developed it into a full conceptualization. Henceforth when we use the term 'transdisciplinarity', we refer to Nicolescu's conceptualization. Interestingly, or perhaps quite understandably, Nicolescu transcended his own discipline of quantum physics the same way as the above mentioned scientists. He is also comfortable in the realms of philosophy, art and religion. Now we try to work out how this conceptualization of transdisciplinarity can work in the human-social studies, whether we see any limitations or barriers, and what we can learn from this attempt. There were numerous applications of transdisciplinarity to particular problems in human-social studies, but here we are interested in the overall knowledge domain – not in a particular problem. Before applying transdisciplinarity as a lens for our inquiry, we need to explain how we understand Nicolescu's conceptualization.

Before we discovered Nicolescu's [38; 39; 40] work we constantly tried to position ourselves within multi- and/or interdisciplinarity and we were constantly dissatisfied with what these two concepts could offer. We did not yet know that our approach was, and has always been, transdisciplinary. Here, we want to explain the subtle but significant differences multi-, inter- and transdisciplinarity using a powerful metaphor, which Nicolescu [41] used in his seminar talk. In this metaphor, disciplines are represented by birds in their cages.

A mono-disciplinary approach is when we only have one bird in one cage. This bird, remaining in its cage, observes reality outside its cage, the room that represents the problem area, through the grid of the cage. Looking at this picture from the *outside* it is perfectly clear that what this bird sees is necessarily partial, subjective and distorted. However, from *within* the cage this cannot be seen; the bird can think that it observes reality as it is. If we bring in further birds of different species, each of them in its own cage, we can have a *multidisciplinary* approach. Each bird sees its mono-disciplinary picture but they 'talk' to each other. As the name suggests, it is a multiplication of mono-disciplinary approaches, which presents a far richer picture than what mono-disciplinarity can offer. Still, it has severe limitations. Each observation refers to the complete picture of what each bird can see and, as they belong to different species, their knowledge backgrounds, approaches, ontological and epistemological stances, and also songs (professional jargons) are different. Ultimately, such observations can lead to cacophony of songs, i.e. immensely complicated (but not complex) mutually incompatible results. If we are outside the cages, we will probably leave the room, since all we can hear is immense noise. Most importantly, the birds are still in cages, meaning that we are still bound by disciplinarity.

Interdisciplinarity usually involves fewer birds. Suppose, we temporarily bring over one bird of other species into the cage of another bird from a different species. The host bird will learn a bit of the songs of the guest birds. It may not learn the songs very well, but enough to get something new from them. This can be a new concept, an approach, but most probably a method and/or a tool. For example, a psychologist host bird may borrow a statistical method from a mathematician guest bird, and a harmony concept from a musical guest bird. We don't have a definite answer to the question of whether the adopted method and the new concept will result in a displacement of original concepts [42] in the host bird's original discipline. We believe the answer depends on the docility of the host bird. An interdisciplinary inquiry is not as noisy as the multidisciplinary one; it is somewhat more complex and less complicated. It can lead to meaningful results within the cage of the host bird. The Sword of Damocles of interdisciplinary research is that the presumptions behind the borrowed methods, concepts, etc. may not be synchronized with the background knowledge of the host bird. It is possible that there are hidden irreconcilable inconsistencies. However, if the host bird is docile and learns the songs of the guest birds well, the quality of such inquiry can be excellent. Still, the notion of interdisciplinarity is very limited, since the birds remain in cages. However, the docility and second-language knowledge of the host bird can expand the cage.

Now, let's open the cage doors, and let the birds fly outside of their limited habitats. This new setup brings us into *transdisciplinarity*. The birds are freely flying beyond their cages, although most of them will probably choose to return to their cages sooner or later in order to eat and rest. We are all most comfortable within our own disciplines, but many of us also find our disciplines limiting, and even boring at times. Some of us may even fall in love with the second-language songs so much that we keep whistling them after our guests return home. Bourdieu, Nicolescu, and Einstein are excellent examples of this phenomenon. The greatest thing about transdisciplinarity is that it goes beyond the disciplinary boundaries *in principle*, not only beyond the boundary of a particular discipline. Transdisciplinarity does not just allow us to visit a different cage; it gives us an opportunity to create new knowledge in the no man's land between cages. Such knowledge may achieve immensely high complexity but should not be very complicated. The birds now seem to be perfectly in tune, as they are together in the space between the cages, and we hear one beautiful, harmonious, polyphonic song.

Teaching about decisions has been multidisciplinary for a long time, and it still is. In business schools operational researchers build quantitative models based on linear programming (and its recent advances) or statistics and probability theory. In schools of psychology, cognitive psychologists focus on the role of memory and biases, while others detail aspects of personality and motivation. Some economists calculate expected utility functions, while other economists who are better mathematicians build simulated models based on game theory. Operational researchers, psychologists and economists rarely talk to each other or use each other's work. In contrast to teaching, decision *research* has predominantly been interdisciplinary. We could list the previous examples of operational researchers, psychologists and economists; the difference would be that there is some interaction. Sometimes a tool, a method or a concept is borrowed, occasionally a model or another form of result is lent. These disciplines, and some additional ones, such as artificial intelligence, social psychology and philosophy, meet around a problem domain that is currently known as 'cognitive sciences'. This is a very good label, as it signifies the multiplicity of disciplines. However, the *reality* of decisions has always been transdisciplinary. Thus, being engaged with practicing decision makers, our approach has become transdisciplinary as well – only we did not know what it was called.

Transdisciplinarity offers some methodological guidelines for scholars. Following these guidelines, we distinguish between various levels of reality, similarly to Russell's logical types [43]. On each level of reality, bivalent logic may be valid; however, transdisciplinary also transcends bivalent logic. This means that something and the opposite of something can hold true at the same time. Using the notations of logic this means that something can be ***A*** and ***non-A*** at the same time; Nicolescu call this third possibility T, the 'hidden third'. **T** is obtained by the synthesis of ***A*** and ***non-A***, as Fichte [44] did in his thesis-antithesis-synthesis cycle[4], and this is what we can see in the Taoist tradition of Yin and Yang. This synthesis enables moving between the levels of reality.

Now, after introducing our soft approach at a philosophical level, meta-knowledge at a methodological level and transdisciplinarity at a conceptual level we are ready to introduce our new model of decision making.

8.5 A New Model: The Realities of Decision Making

After this triple detour, in this section we finally outline our main point: a new model of decision making. Based on decades of combined experience in teaching, observing and working with decision makers, we realized something very important. It is impossible to support decisions; we can only support decision makers. In order to portray decision making as we see it, we use a transdisciplinary lens, so that we can observe the decision maker as birds flying freely between the cages. At the core of decision making we focus on meta-knowledge, which we argue is necessarily tacit. And we bring in the soft approach, as the antithesis of the hard, to achieve a synthesis in order to move between the realities, that is, levels of reality which thus becomes more nuanced.

Therefore, for the sake of our exploratory thinking presented here, we describe decision making with the following three levels of reality:

1. Model of the decision maker's behavior.

[4] Typically but incorrectly attributed to Hegel's dialectic. Although Hegel did not introduce or use the triad of thesis-antithesis-synthesis, transcending dichotomies is an important aspect of Hegel's idealism.

Table 8.1: Levels of Reality of Decision Making

		Model	**Method**	**Tool**
Observed	A	rule-following	MCDA	BI
	Non-A	misbehaving	intuition	expert system
	T	cognition	complex order	SmArt tool
Observer	A	Homo Calculator	algorithm	(big) data analytics
	Non-A	Homo Ludens	non- or quasi-algorithmic	knowledge engineering
	T	Homo Sapiens	complex system	experience mining(?)

2. Method used to support the decision maker.
3. Tool we use to implement the support of the decision maker.

On each of these levels, we distinguish the observer and the observed, and for each of them provide the ***A***, ***non-A*** and ***T*** the following way (see Table 8.1):

At the model-level, the decision maker (in a particular decision situation) can be a *rule-follower* (***A***) or a misbehaver (***non-A***). The notion of the rule-follower is linked to March's [45] concept of 'appropriate action', according to which decision makers do what is expected from them. That is they follow the rules, not only the standardized procedures, but also the expected behavior. In contrast, those who misbehave [18] demonstrate notorious neglect of not only expected behavior, but often also of the standardized procedures. As behavioral patterns, the two (***A*** and ***non-A***) can be considered mutually exclusive: those who follow the rules do not misbehave, and those who misbehave do not follow the rules. However, the two contradictory behavioral patterns can be synthesized in a more complex cognition (***T***). The decision maker using both hard and soft approaches knows the rules and follows them when necessary and/or useful, but also knows which rules can be broken under which conditions and how often. Such decision maker will demonstrate both rule-following as well as misbehaving behavioral patterns. In observing the decision maker we can see a Homo Calculator (***A***), the person who mainly does mental accounting [18]. Or a Homo Ludens (***non-A***), a playing man, who is playful and curious like a child, who allows her-/himself to admire the worlds wonders. As a synthesis, we can see a Homo Sapiens (***T***), a wise man, who finds the harmony between playing and calculating. Such a decision maker measures what can be measured, calculates what can be calculated, but does not force measuring and calculating on things that cannot be measured and calculated. This is when (s)he uses her/his imagination.

At the method-level, the rule-following decision maker uses a variant of*MCDA* (multi-criteria decision analysis), nearly always in a quantitative mode (***A***). The misbehaving decision maker, in contrast, uses *intuition* as a 'method' [14], they refer to their gut feel, hunch, overall experience, etc. (***non-A***). Indeed, only experienced decision makers should use their intuition [46]. The synthesis of the two methods we call '*complex order*' (***T***). This signifies both that this order cannot be reduced to a simple one or several simple ones (which would only be complicated but not complex), and also that it is multidimensional. Intuition and well-structured analysis are not only side-by-side but also hand-in-hand; it may involve intuitive reinterpretation of the analytical findings as well as new analysis based on a hunch, etc. [cf 47;

48] As observers, we see the Homo Calculator using *algorithms* (***A***), in the sense of following recipes, assuming that these are eternally and universally valid, and they are often surprised why the recipe does not work. In contrast, what the Homo Ludens does is often *non-algorithmic* or, at least, *quasi-algorithmic* (***non-A***). Non-algorithmic here means that it appears arbitrary to us, we cannot detect any series of logical steps. Quasi-algorithmic, in turn, means that we may see shorter or longer sequences of steps, but not an overall designed process, the steps may go now this way then another way. As a synthesis (***T***), we can observe a *complex system*, as in Boulding's [49] levels 7-8 (human and social) of systemic complexity, including emergent phenomena that cannot be reduced to the level of the thermostat (level 3).

At the tool-level, the rule-following decision maker, who adopted an MCDA method uses some form of BI (business intelligence), to implement the method, not necessarily knowing what the chosen BI-tool does (***A***). In contrast, misbehaving decision makers, who use their intuition, usually feel that they don't need a tool. However, they also often feel that they benefit from a good conversation with someone who can be a partner in this, such as a good coach. Nevertheless, there is one type of tool that can be useful in supporting such thinking: *expert systems* (***non-A***). Expert systems can help organize the thinking of such decision makers in a transparent way, which can be particularly useful for explaining the hidden logic behind their intuitions. Synthesizing these two tools we get what we call *SmArt decision tools* (***T***). Making both the 'S' and the 'A' capital signifies that this is as much 'Art' as 'Smart'; it incorporates both analysis and soft approaches, such as expert systems. As yet we have conceptualized the SmArt Tool, but we must admit the tool does not currently exist. Observing the tools decision makers use, we can see that the Homo Calculator, who follows algorithms, relies on data analytics, which is increasingly taking the form of big data analytics (***A***). This shift towards big data analytics is unfortunate, as it is based on the conviction that the way to improve data analysis is through analyzing more data, rather than by doing more thinking. We refer to this phenomenon as 'big data – small insight'. The Homo Ludens with her/his non- and quasi-algorithmic methods can be supported through *knowledge engineering* (***non-A***). Knowledge engineers are a special kind of facilitators, who build expert systems by acquiring knowledge from the decision makers and organizing this knowledge into knowledge bases. Finally, synthesizing [big] data analytics with knowledge engineering will require a new concept. One possibility would be something that we tentatively call experience mining (***T***), which is a way of finding and adapting relevant experience to the current decision problem. Many aspects of the way experience mining will work are yet unclear. This is what we signify with the '?' symbol (Table 8.1). We do not know yet what the process will look like that incorporates both [big] data analytics and knowledge engineering. First, we will need to create a SmArt tool, so that we can then develop the process for using it. We have some ideas about what this process could be, but the development of the tool does not follow a prior design of a well-structured process. Cars were not developed after the process of driving and traffic system were designed; arguably cars, driving and traffic systems all would be very different today, if the latter were designed first. Furthermore, once we can get rid of the question mark, regardless of whether we end up with experience mining or another new concept, we may be able to recognize the next level of reality.

This is how we see decision making today, using the lens of transdisciplinarity based on Nicolescu's conceptualization. These are the three levels of reality that we can see. Based on the '?' in the final cell of Table 6.1, we also see a few things about the possible fourth level of reality, which will inform the way we teach about fast decisions tomorrow. For example, we see that tomorrow's decision makers are Shallows [50], whose attention needs to jump after a very short time (approximately 15 minutes at most) even when they are doing something exceptionally exciting, such as listening to a good teacher.

8.6 Concluding Remarks: Teaching about Fast Decisions Tomorrow

We believe that our audience tomorrow will be Shallows. In addition, we have argued that neither the teacher nor the practitioner are really suitable to teach about decision making. So, who should be teaching, what should they be teaching, and how, when it comes to decision making?

The 'what' here consists of two parts; both covered in this essay. First, the topics should be along the lines of our table, or an alternative view of decisions. The particular topics are not important, what matters is that they are fresh and based on a coherent 'big picture' of decision making; what the teacher sees 'then and there' [cf 'egocentric particulars' in 51]. This is primarily important from the viewpoint of credibility: if we teach something other than what we believe in then it will be perceived as inauthentic by students. However, it is also important in the sense of not delivering outdated knowledge, as the world of decision making is changing too fast. Second, the topic should be delivered in the form of meta-knowledge. This is, again, important for two reasons. On the one hand, meta-knowledge is more applicable to different real-life situations. If we could elaborate in detail what works in a particular decision situation, this would only work in that single situation, nowhere else. Meta-knowledge, as showcased earlier, can take different shapes in different real-life situations. On the other hand, in any classroom where we have practitioners, we will have people with a wide variety of knowledge backgrounds – only meta-knowledge can transcend the limitations of existing knowledge variety.

The most appropriate person to teach decision making could be described through the metaphor of the 'coffeehouse philosopher'. By this we mean a person who speculates about the big questions of the human condition, the universe, love, and similar important topics, while sitting in the coffeehouse and watching people as they go about their real lives. The coffeehouse philosopher is not embedded in the real world of practicing decision makers, but is also not completely removed from it. Ideally this would be a wise person who started to figure out something important – it does not really matter what that 'important something' is. However, the coffeehouse philosopher should not do this teaching alone. There should be guests, practicing decision makers whom the coffeehouse philosopher will interview live in front of the students. If this works well, both the coffeehouse philosopher as well as the practicing decision maker will produce meta-knowledge for the students.

This brings us to the 'how' of teaching. We believe in storytelling. Stories work much better than dry, abstract models, for a number of reasons. Our students, who are Shallows and practitioners themselves, will find it easier to relate to stories than to abstract models and thus achieve an intuitive understanding. Also, good stories are much easier to remember. At least two types of stories should be told in our classroom: metaphoric parables by the coffeehouse philosopher and real-life stories of concrete experience by the practicing decision makers.

Finally, we need to separate teaching from learning rather than assuming that learners learn what teachers teach. Our starting point here is that our Shallow practitioner students have decisions they need to make, and that we cannot provide them with the solution, because we are not part of the specific context, and even if we could, it would be of extremely limited use for the next decision they need to make. We call the mode in which we can help them *bootstrap learning*. We derive the conceptualization of bootstrap learning from Popper's [24] tentative problem solving process. Popper initially conceptualized the process as interpreting the earlier mentioned 'dialectic triad' (thesis-antithesis-synthesis) as a trial and error-elimination process. In doing so, he identified the following schema:

$$\boldsymbol{P1 - TT - EE - P2} \tag{8.1}$$

Where P1 and P2 stand for problems (in our case there is a decision that need to be made), TT stands for a tentative theory (through which the decision situation is interpreted) and EE stands for error elimination (something we are unhappy about in the TT). It is important to note that in the later revisions of this idea Popper emphasized that *any* of the three components could be a legitimate starting point of the tentative problem solving process (in the initial version that starting point was the P1 problem). In our bootstrap learning this would mean that the meta-knowledge can connect to any of the three components, changing how the learners see them. So the meta-knowledge can help the learners see any of the P, TT, EE differently than before receiving the meta-knowledge. However, the meta-knowledge does not provide them with a solution, only with some ammunition, using which they can bootstrap themselves from the problem situation. In future decision situations, our students will re-use some of the meta-knowledge the same way to make fast (intuitive) decisions. In this sense, in bootstrap learning it becomes very explicit that what is taught and what is learned are two different things.

In conclusion we want to remark that we do not think that this is what the teaching about fast (intuitive) decisions will look like in the future; this is only how we see future teaching about fast (intuitive) decisions today. There are countless unforeseen and unforeseeable circumstances, political agendas, new technologies, societal changes, etc. that will lead to a different reality tomorrow. However, this is what we work towards today, and even if the world will be different tomorrow than the tomorrow we envision today, we will be closer to the reality of tomorrow than those who work on assumptions which were outdated yesterday. We have the ***A*** of tomorrow today, there will be a ***non-A*** that we don't know about yet, and there will be a ***hidden third*** version of tomorrow emerging on a new level of reality. Therefore, tomorrow we will rethink again what and how to teach about decisions. We will continue wandering at the mystery of decision making, as:

> *The fairest thing we can experience is the mysterious. It is the fundamental emotion which stands at the cradle of true art and true science. He who knows it not and can no longer wonder, no longer feel amazement, is as good as dead, a snuffed-out candle. [52]*

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CHAPTER 9

Objectives are Subjective

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Besides being very actual and controversial, the problematic of risk management and decision-making raises again questions about human capabilities of planning and achieving planned goals. This paper is intended to indicate some possibilities to approach risk assessment and risk management according to the transdisciplinary (TD) methodology, in a more accurate and at the same time, more consistent and more effective way.

Keywords*:* risk, decision-making, object, subject, transdisciplinarity.

9.1 Introduction

Historically, several attempts were made to understand and even formalize the risk assessment processes and the subsequent decision-making. Similar attempts are still made today. Both risk management practitioners and theorists are facing multiple challenges arising from the inherent limitations of disciplinary approaches, since current developments in this area don't provide significant improvement of practices and understanding of risk and decision making processes.

Usually, the most common risk definitions emphasize elements of uncertainty and/or magnitude of impact and consequently, trigger approaches, concepts, methods and measurements of the same nature. These are the methods used today. At the same time, many disciplinary perspectives involve sophisticated concepts and methods, as applicable. However, today it is already obvious that the increased complexity of human activities has shown the "limitations" (read: failures) of the approaches used currently. Failures are not due only to the intrinsic reductionism of the disciplinary approaches. One of the main causes is of a fundamental nature, since "risk" is neither (and cannot be) absolutely objective, nor absolutely subjective. Therefore, "risk" doesn't have a standalone existence either objectively, or subjectively.

Ignorance	**Risky Situation**	**Complete Knowledge**
Pure Uncertainty	**Probabilistic**	**Deterministic**

Figure 9.1: Decision-making domains.

9.2 Beyond definitions

Academic research, Figure 9.1 [1] indicates that a relationship between "planned" and "achieved" can belong to three domains, "[...] one "pole" on this scale is deterministic. [...] The opposite "pole" is pure uncertainty. Between these two extremes are problems under risk. [...]" (see Figure 9.1).

This type of classification is rigorous and very useful within the accepted boundaries, but nevertheless, limited. It is an intrinsic limitation, due to the mere disciplinary nature of the approach. It does not (cannot and doesn't have to) cover the variety of uncertainty types, as encountered in our common experience.

Without comparing the deterministic domain and the domain between "probabilistic" and "pure uncertainty" and solely relying on common experience it can be said that uncertainties are of many different kinds, belong to many areas and reveal the complex nature of the problem.

In order to deal with complexity, it seems necessary to use another approach since the current ones do not (cannot and don't have to) cover the description of the context for the decision-making process, the formulation of an objective (as a distinct process), nor the decision-making process itself.

The most recent and very rigorously elaborated definition of risk [2]: "Risk: 'effect of uncertainty on objectives"' illustrates/ re-discovers in a very pragmatic manner, the fundamental need for a subject and an object, as well as of their interaction. Similarly, the activities aimed at managing risks are also defined through: "Risk Management: 'Coordinated activities to direct and control an organization with regard to risk.' ". Such a dependence on the subjective definition of an objective is demonstrated in many instances, but for illustration purposes only, I have chosen the following example in Figure 9.2 [3], entitled "Corporates mean different things when they talk about enterprise risk management",

Without an objective (formulated, validated and pursued by some "subjective" entity - could it be otherwise?) risk cannot exist. To better illustrate the interaction of the three elements, I use Figure 9.3, an adapted form of the graphical representation of the Subject – Object relationship [4].

Since "formulated objectives" are subjective, the emergence of "risk problematic" is possible only in the subject area, whereas the "result: effect of uncertainty" is supposed to belong the object area (Figure 9.4).

An ideal cause-effect relationship, deterministic and even probabilistic in nature is represented through a black arrow. As mentioned above, such relationships are quite seldom in our common lives since our lives are complex. An honest evaluation can show that decision-making in the context of e.g., roulette gambling or variations of the stock exchange markets are less complex than decision-making related to our daily survival, and of course less frequent. Therefore, it is no exaggeration to state that such "straight-line" (ideal) relationships are an exception, a mere accident, whereas the real relationship could be "described" by means of the purple line.

Figure 9.2: ERM goals are different for different industries.

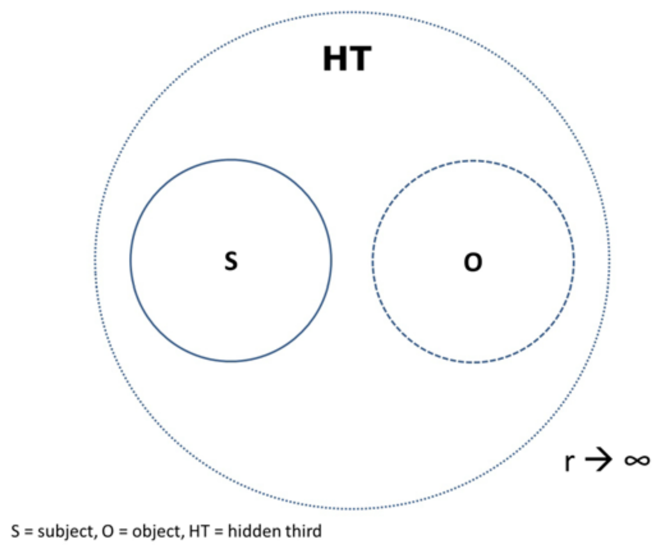

Figure 9.3: Subject – Object relationship.

Figure 9.5 shows the gap between "desired" and "achieved" or to follow the definition above, "the effect of uncertainty on objectives".

But again, what uncertainty?

Our planning and decision-making processes are inherently affected by uncertainty. Following the TD methodology, it is possible to acknowledge that the inherent

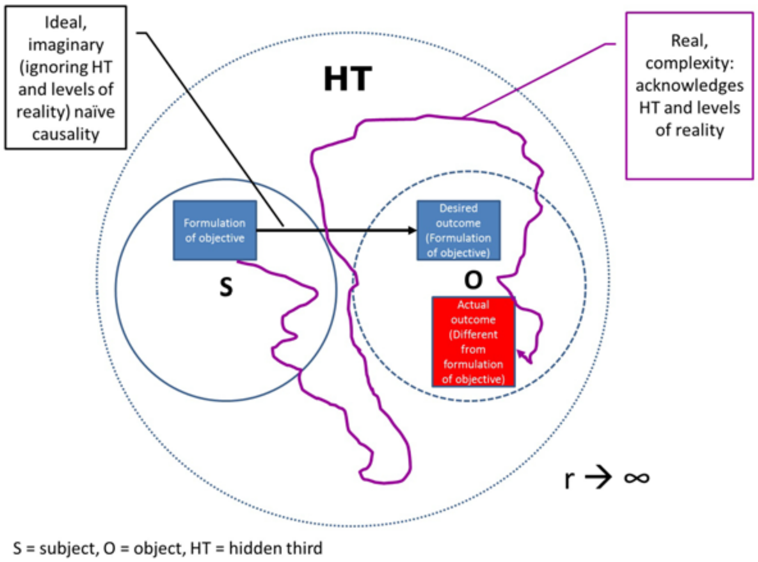

Figure 9.4: Relationship between "formulation of objective" and "outcome".

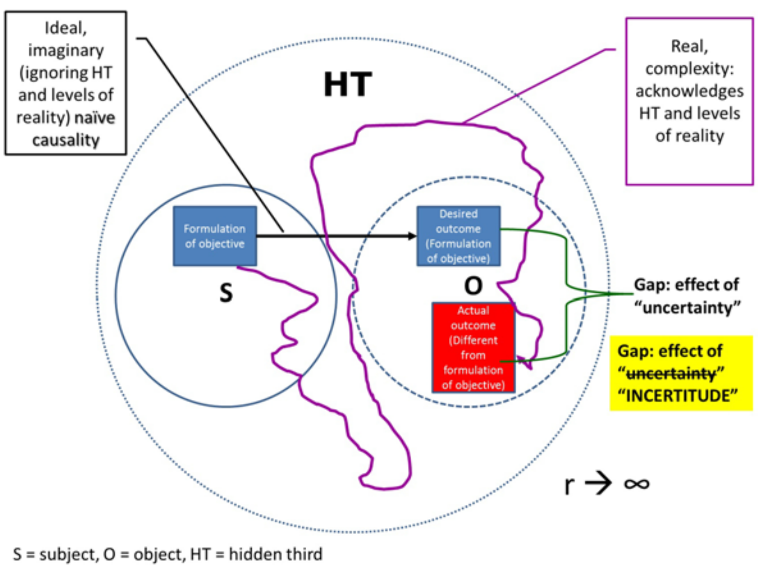

Figure 9.5: Gap between "desired" and "actual" outcomes.

"sources of uncertainty" could be attributed both to the nature of the Subject-Object-Hidden Third interaction (Figure 9.3) and to the zone of non-resistance between the levels of reality of the Subject and of the Object. I used the quotation marks, because discovering under this disguise (i.e. as a "source of uncertainty") the action of the Hidden Third in relation to the Subject and the Object is at least, astonishing.

At the same time, the "uncertainty" attributed to the zone of non-resistance between the levels of reality is more apparent through the obvious biases pertaining to the identification and evaluation of risks, as well as to the planning of treatment actions, both on the Subject and Object sides. This aspect is outlined especially through the recognition of biases and the acceptance of their impact on risk assessment and decision-making [5].

These considerations are far from being just theoretical, or of epistemological relevance. It can be firmly stated that corporations today started to acknowledge the impact of biases and either accept it, or attempting to reduce or avoid it. "[...] debiasing business decision making has drawn board-level attention, as companies doing it are achieving marked performance improvements. [...] Group psychological behavior produces some of the most powerful biases in business settings. Group dynamics can cause managers to sacrifice reasonable dissent to enhance their associations, maintain the favorable perceptions of others, and keep competitors at bay. They may recognize but choose to ignore flaws in the analyses and proposals of their allies, so these kinds of biases are not cognitive in nature – they do not relate, in other words, to the acquisition and assimilation of knowledge. Rather, they are generated by the group setting itself, in which managers almost consciously relinquish good logic as they compare and evaluate options for action. [...]" [6].

Figure 9.6 [7] illustrates better the considerations above, while assuming that an event is defined as A: "Objective completely achieved as desired" (blue square), whereas its opposite (logical negation) is non-A: "Objective not completely achieved as desired" (red square).

It could also be said that within the accepted structure of Levels of Reality (LR) the problematic situation might be illustrated by means of two epistemological ternaries: Subjectivity – Objectivity – Complexity and Intellect – Body – Emotions/ Feelings in relation to evaluating and prioritizing decisions and activities. The next paragraphs will outline an improved classification of the uncertainty types as well as of the risk treatment activities.

9.3 Re-formulation of the problematic situation

From a disciplinary perspective, one of the most relevant classifications of uncertainties is presented in [8], Figure 9.7.

While fully acknowledging the "effect" of the Hidden Third in all aspects of knowledge and their combinations as outlined in this table (and the relevance of both epistemological ternaries), it is also possible to ascribe specifically to each type of knowledge (respectively, about likelihoods and outcomes) the impact of non-resistance zones between the Levels of Reality of the Subject and of the Object (where the ternary Intellect – Body – Emotions/ Feelings is particularly relevant). Treatment actions would be adapted accordingly.

The same paper includes the following descriptions of the combinations derived from the degree/ quality of knowledge of likelihoods and outcomes:

- "[...] RISK is the zone where outcomes and likelihoods are reasonably well known. This is the region of risk analysis or risk assessment, where various outcomes are looked at for the 'dangers' that they carry.

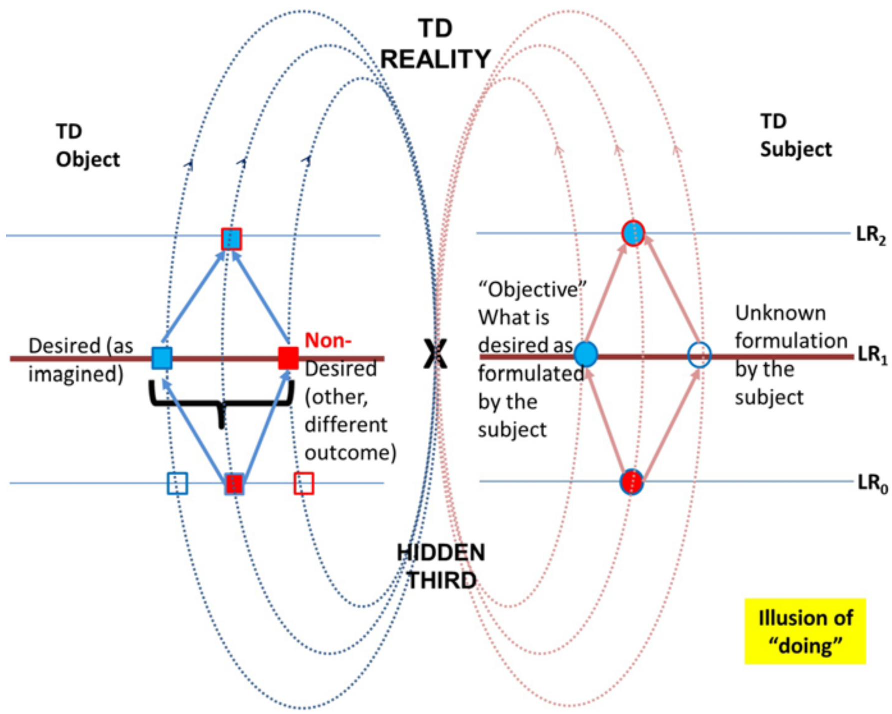

Figure 9.6: Levels of reality; gap between "desired" and "actual" outcomes.

- UNCERTAINTY applies where there are no firm bases for probabilities, yet some reasonably clear idea as to outcomes should an adverse probability come into play.
- AMBIGUITY applies to circumstances where the outcomes are not clear, but there is evidence of likelihood that is reasonably well known.
- IGNORANCE applies where there is an innovative technology or a product or substance that is synthesized and is not replicated in nature, and where there is no history of cause and outcome to predict consequences. This means that science cannot, by its own rules predict either likelihood or outcome. [...]"

Recent surveys [9] indicate a close correlation between improved performance of investment decisions and five elements that are directly connected to the subjective aspects of decision making for investment. However, some survey results indicate that "[..] when deliberating over investment and other strategic decisions, managers have many practices at their disposal to ensure sound decision making: presentation of information that contradicts leaders' views, for example, and explicit discussions of the range of potential outcomes. Only 60 percent of respondents agree that decision makers explicitly discuss uncertainties when making resource-allocation decisions. And only 41 percent agree that their companies consider a range of potential outcomes or scenarios for a given investment."

To illustrate the potential for improvement, one has to note that even in the case

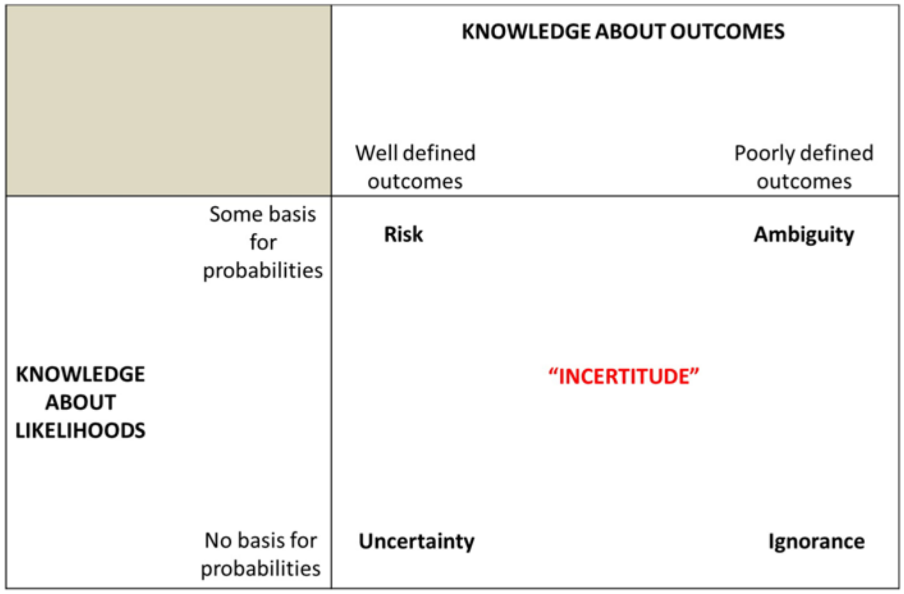

Figure 9.7: knowledge of outcomes, likelihoods and "incertitude".

of evidence-based decision making only "[..] when asked which specific techniques their companies' managers use to improve decision making, the largest share of respondents, 59 percent, cite scenario analysis. But no more than one-third cite any of 12 other commonly referenced checks on biases, such as pre-mortems, postmortems, and explicit meeting rules. (We define "pre-mortems" as an analysis of what can go wrong or right before the project is under way and "postmortems" as an analysis of what went wrong or right after the project is completed. "Explicit rules for meetings" could include getting all ideas onto the table before discussing and/or the CEO expressing his or her opinion after everyone else on the management team or group has done so.) Nevertheless, the results suggest that the use of such techniques can lead to better performance. Respondents whose companies make the most use of evidence-based decision making are 36 percent likelier than their peers whose companies don't use these techniques to report growing faster than competitors. And they are 22 percent more likely to say their companies are more profitable. [...]".

Therefore, using the TD methodology has a significant potential for improving both the techniques for decision making and the decision-making process itself. A more detailed presentation will be made available in a separate article. For the moment, I will use Table 9.1 to outline the connection between the above mentioned disciplinary findings (types of uncertainty), treatment strategies and the TD concepts (since all concepts in the TD methodology are applicable, I indicate only those of immediate relevance and manifestation on the correspondent type of "incertitude").

Management strategies will be improved specifically based on the TD concepts and using the epistemological ternaries for contextualization. In this respect an important part is played by the description/ characterization of risks and "incertitude" types. The next section will provide more detail about description and risk

Table 9.1: "Incertitude" and Concepts of TD Methodology

Type of "incertitude"	**Management strategy**	**TD concept**
Risk	Science based	Levels of Reality (Subject – Object)
Uncertainty	Precautionary	Levels of Reality (Subject – Object), non-resistance zone
Ambiguity	Precautionary/ Discourse based	Levels of Reality (Subject – Object), non-resistance zone, Hidden Third
Ignorance	Precautionary/ Discourse based	Levels of Reality (Subject – Object), non-resistance zone, Hidden Third

dimensions.

Of particular relevance for the potential TD developments are the articles and working papers published by Andreas Klinke and Ortwin Renn since their approach is already interdisciplinary [10]: "[...] The interdisciplinary risk estimation comprises two activities:

1. Risk assessment: producing the best estimate of the physical harm that a risk source may induce;
2. Concern assessment: identifying and analyzing the issues that individuals or society as a whole link to a certain risk. For this purpose the repertoire of the social sciences such as survey methods, focus groups, econometric analysis, macro-economic modeling, or structured hearings with stakeholders may be used.

There are different approaches and proposals how to address the issue of interdisciplinary risk estimation. The German Advisory Council on Global Change (WBGU) has developed a set of eight criteria to characterize risks beyond the established assessment criteria [...]". Introducing the process of "concern assessment" facilitates the introduction of other risk dimensions and provides a starting point for a TD approach since consideration is given also to "framing" [11].[1]

9.4 If Risks Exist, These Have More Than two Dimensions

Commonly, for the description and communication of risks, special emphasis is put on two dimensions relevant to the specific risk scenario: magnitude of impact/ effect (adding "on objectives" according to above mentioned definition) and likelihood of occurrence (already detailed in the previous section).

Klinke and Renn [10] suggest the following criteria/ dimensions:
"[...]

- *Extent of damage*: Adverse effects in natural units, e.g., death, injury, production loss, etc.
- *Probability of occurrence*: Estimate of relative frequency, which can be discrete or continuous.
- *Incertitude*: How do we take account of uncertainty in knowledge, in modeling of complex systems or in predictability in assessing a risk?
- *Ubiquity*: Geographical dispersion of damage.
- *Persistence*: How long will the damage last?
- *Reversibility*: Can the damage be reversed?
- *Delay effects*: Latency between initial event and actual damage.
- *Potential for mobilization*: The broad social impact. Will the risk generate social conflict or outrage etc.? Subcategories here are:

[1] According to Robert Entman, to frame is "[...] to select some aspects of a perceived reality and make them more salient in a communication text, in such a way as to promote a particular problem definition, casual interpretation, moral evaluation, and/or treatment recommendation for the item described [...]"

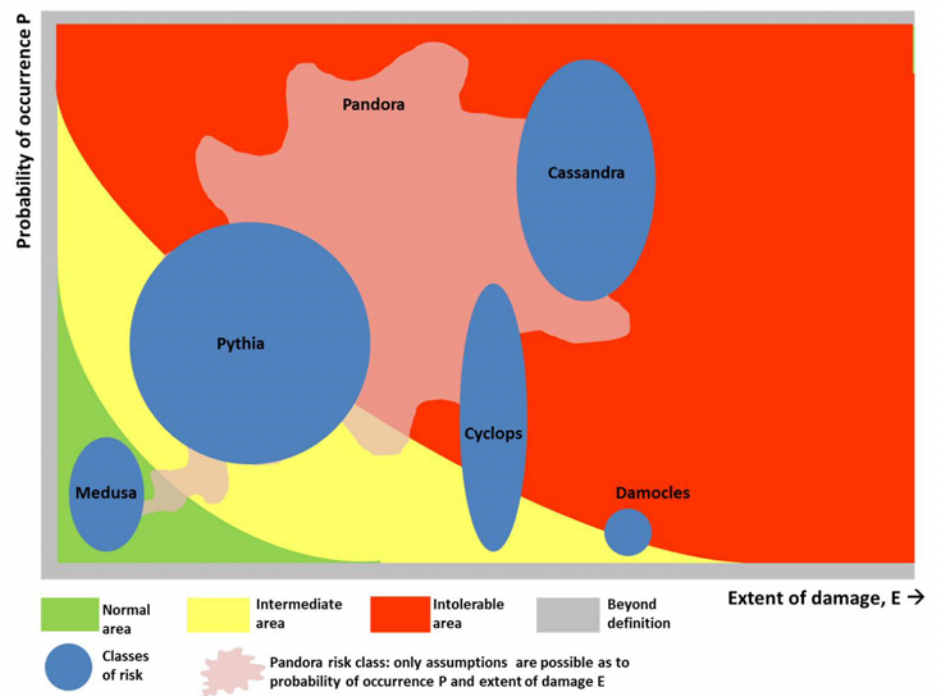

Figure 9.8: knowledge of outcomes, likelihoods and "incertitude".

– *Inequity and injustice* associated with the distribution of risks and benefits over time, space and social status;
– *Psychological stress and discomfort* associated with the risk or the risk source (as measured by psychometric scales);
– *Potential for social conflict and mobilization* (degree of political or public pressure on risk regulatory agencies);
– *Spill-over effects* that are likely to be expected when highly symbolic losses have repercussions on other fields such as financial markets or loss of credibility in management institutions.[...]"

Of particular interest for using a TD methodology in the future approaches are the names from the Greek mythology used by the authors for risk categories. These names are not only very illustrative, but describe in a much more accurate way the Subject-Object relationship. While considering the already classical "impact-likelihood" dimensions it is possible to see in Figure 9.8 [12] a good indication of how several dimensions are used for improving the risk classification.

In the same article, the authors state "[...] they (myths, T.N.) are, however, reminders of the genuine forces that are inevitably present in the making of new technological eras. They can guide us through the clouds of uncertainty and ambiguity associated with new scientific advances and technological breakthroughs. Far from providing recipes for managing technologies and risks, they can help us to orient ourselves in the tension between courage and caution and to create powerful images that provide sources for understanding and handling risks in modern societies.

Also [13], "[...] Although history has recorded numerous examples of unwarranted anxieties, there have been equally worrisome accounts of overconfidence in allegedly fool-proof safety measures and human abilities to cope with disasters. The responses to the change of technology over time seem to oscillate between the carelessness of Epimetheus and the foresight of Prometheus, between the real disasters of Pandora's box and hope, the ultimate gift of the gods to humankind. [...]"

And it is remarkable to note that in the field of risk management researchers and practitioners started to accept the limitations of the so-called "scientific" or "objective" approaches and try to fundamentally improve their practice and research. The TD methodology allows this improvement of a fundamental character [14], since "[...] Transdisciplinarity means "beyond" disciplines not in the sense of dismissing them but removing their intrinsic claims to a single knowable reality and epistemology. [...]". I am quoting this article, as it contains a similar description of the effort to rediscover a more accurate and at the same time, sincere Subject-Object relationship: "[...] Like psychology itself, "literary studies" was invented in the nineteenth century under the influence of the proliferation of disciplines sponsored by the dominance of empirical science. These new disciplines were the "Social Sciences," meant to employ the objectivity of science to human and cultural matters. Objectivity means just what The Red Book laments. That Jung had found the human soul [15]: "I had judged her and turned her into a scientific object." Similar "objectivity" [14] pervaded literary studies in the twentieth century with the determination of its "New Criticism," that the text was an object, sufficient in itself to generate knowledge with no participation from either the personality of its author or its reader. [...] Here we see disciplinary division as a primary severing of being. [...]"

Therefore, based on interdisciplinary research and after acknowledging the need for a better classification and description of risks, the basis is set for a TD approach.

The potential for TD developments is described in the following table, synthesizing the categories of risks, their names, subsequent treatment strategies, epistemological ternaries relevant to the TD approach and derived from these, managerial actions (suggestions at tactical level).

Table 9.2 outlines several risk classes and treatment strategies and TD concepts are emphasized for each risk class. At the same time, our current experience could be summarized in the statement of Klinke and Renn [16], "[...] most risks are characterized by a mixture of complexity, uncertainty, and ambiguity. Smoking may be a good example for low complexity and uncertainty but high ambiguity. Nuclear energy may be a good candidate for high complexity and high ambiguity but relatively little uncertainty. Endocrine disrupters could be cited as examples for high complexity, uncertainty, and ambiguity. [...]"

It should be noted that strategies and tactics derived especially from the application of the epistemological ternary Intellect – Body – Emotions/ Feelings have an important role in dealing with ambiguity or ambivalence. By definition, TD methodologies will assist in (1) interpreting factual statements about the problem (e.g., mobile phones, pesticide residues in food) and (2) reconciling the differences in applying normative rules to a specific situation (e.g., ban or no ban on smoking).

Nevertheless,"[...] high complexity and uncertainty favor the emergence of ambiguity, but there are also quite a few simple and almost certain risks that can cause controversy and thus ambiguity. It is therefore important to distinguish between complexity, uncertainty and ambiguity: these three terms are correlated but they are not identical."

9.5 Conclusions

The increased complexity of human activities has shown important and costly limitations in the field of risk management and decision making. The article shows the possibility to connect findings from disciplinary and interdisciplinary research and practice in order to develop a transdisciplinary (TD) approach. Based on TD methodology it is possible to improve both the techniques for decision making and the decision-making process itself.

Current and future results of research and practice will be presented in detail as a continuation of this article.

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Table 2: Risk Classes and Concepts of TD Methodology

Management	Risk class	Extent of damage	Probability of occurrence	Ambiguity	TD concepts Contextualization/ TD epistemological ternaries	Strategies for action at tactical level
Science-based (Complexity)	***Damocles*** (technological risks such as nuclear energy, large-scale chemical facilities and dams)	**high**	**low**	**Low**	**Levels of reality (O); Subjectivity – Objectivity – Complexity**	• Reducing disaster potential • Ascertaining probability • Increasing resilience • Preventing surprises • Emergency management
	Cyclops (earthquakes, volcanic eruptions, floods, appearance of infectious diseases, nuclear early warning systems)	**high**	**uncertain**	**Low**	**Levels of reality (SO), non-resistance zones; Subjectivity – Objectivity – Complexity and Intellect – Body – Emotions/ Feelings (assessment of probabilities)**	
Precautionary (High incertitude)	***Pythia*** (global warming, instability of the West Antarctic ice sheet, genetic engineering in agriculture and food production)	**uncertain**	**uncertain**	**Significant**	**Levels of reality (SO), non-resistance zones; Subjectivity – Objectivity – Complexity and Intellect – Body – Emotions/ Feelings**	•Implementing precautionary principle • Developing substitutes • Improving knowledge • Reduction and containment • Emergency management
	Pandora (human interventions in the environment also cause wide ranging, persistent and irreversible changes without a clear attribution to specific damages)	**uncertain**	**uncertain**	**Significant**	**Levels of reality (SO), non-resistance zones; Subjectivity – Objectivity – Complexity and Intellect – Body – Emotions/ Feelings**	
Discursive (High ambiguity)	***Cassandra*** (death, the delay effect leads to the situation that no one is willing to acknowledge the threat)	**high**	**high**	**High ("Low" due to delay effect)**	**Levels of reality (S), Hidden Third; Subjectivity – Objectivity – Complexity and Intellect – Body – Emotions/ Feelings**	• Consciousness-building • Confidence-building • Consensus seeking • Public participation • Risk communication • Contingency management
	Medusa (electromagnetic fields, eutrophication, smoking, extent of damage was assessed as low by most experts; neither epidemiologically nor toxicologically significant adverse effects could be proven. Exposure, however, is wide-ranging and many people feel involuntarily affected by this risk)	**low**	**low**	**Significant**	**Levels of reality (SO), non-resistance zones; Hidden Third; Subjectivity – Objectivity – Complexity and Intellect – Body – Emotions/ Feelings**	

CHAPTER 10

Biomimetic Engineering Analysis of Heliotropic Plants

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Biomimetics is the field of study that identifies potential useful biological processes and mechanisms in nature and translates these principles into the engineering domain. Utilizing nature's abilities has proven to be a powerful and useful mechanism for innovation, and has led to profound technical advancements and capabilities in applied science disciplines and fields. The main objective of this paper is to introduce a Biomimicry analysis of the plants' ability to maintain optimal sunlight in order to maximize the photosynthesis process. The main components and factors that enable heliotropism are discussed as well as the governing physics describing the processes needed in order for this phenomenon to occur in nature. The reader should emerge from this paper with an understanding of how plants are induced by sunlight as well as the long-term possibility of replicating this phenomenon for human purposes.

Keywords*:* Biomimetics, Biomimicry, Heliotropism, solar tracking, transdisciplinary research.

10.1 Introduction

In a time when energy costs continue to increase and concerns associated with an over dependence on fossil fuels, it is advantageous for engineers and companies to capitalize on the technological advances and capabilities that allow us to replicate nature's approach in harvesting energy. Biomimicry is leading the approach to innovation by seeking sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies [1]. Biomimetic engineering is an interdisciplinary approach that identifies potential useful processes and mechanisms in biological systems and imitates them in engineering systems [2]. This engineering approach is initiated by identifying and analyzing a solution offered by nature that may translate to an engineering problem. The underlying principles are understood and transferred to the artificial realm through design, simulation, and fabrication. If possible, affordances and improvements are made within the confines of the technological state [3]. Using the Biomimetic Engineering approach, a common phenomenon that occurs with plants obtaining the most optimal amount of sunlight will be examined, and this process will be considered to provide viable solutions that may produce cost-effective renewable energy for human purposes.

First, a common ground must be established for photosynthesis and the effect heliotropism has in enhancing its efficiency. This must be discussed to show its importance to everyday life and its ability to maximize a process that ensures our ability to live on earth. In grade school, the science curriculum commonly teaches that photosynthesis is responsible for supplying all of the earth's organic compounds as well as the energy required to sustain life on the planet. This process is a complex biological process that harvests light energy from the sun and converts it into biological energy [4]. The energy and carbon is transmitted throughout the ecosystem as the photosynthetic organisms are consumed or decomposed by other organisms in a continuous, revolving circle of life. The principle inputs on the rate of photosynthesis are available water, light wavelength and intensity [5]. However, the main factor that often gets overlooked is how plants ensure they obtain enough sunlight. Sunlight makes up 2 of the 3 important factors in the photosynthesis process. The process responsible for obtaining the precise amount of ideal sunlight for photosynthesis to occur is called heliotropism.

As stated previously, heliotropism enables plants to maintain an efficient level of sunlight in order to initiate the photosynthesis process. However, just knowing this definition at the surface level does nothing to properly quantify the enormity of this capability's impact on the world. Therefore, a number of components and questions need to be addressed in order to fully comprehend this complex everyday process. First, heliotropism is defined as the directional motion of plant parts in response to the direction of the sun [6]. There are several questions that automatically arise when you contemplate the dynamics of a flower tracking and moving in response to the sun. The major questions would be the following:

- How do plants detect the sunlight?
- What mechanisms enable the plant to track the sun?
- What plant features enhance its heliotropism capabilities?
- What are the fundamental physics involved in the process?

The all-encompassing question is, "Can the plant's heliotropism principles be translated by Biomimetic engineering to innovate or improve upon available technologies/strategies employed to harvest renewable energy?" The main objective of this paper is to address the questions above by introducing a Biomimetic Engineering analysis of the plants' ability to maintain optimal sunlight in order to maximize the photosynthesis process. The main components and factors that enable heliotropism are discussed as well as the governing physics describing the processes needed in order for this phenomenon to occur in nature. The reader should emerge from this paper with an understanding of how plants are induced by sunlight as well as the long-term possibility of replicating the principles of this phenomenon for human purposes.

Figure 10.1: The most commonly known heliotropic plant, the sunflower.

10.2 Observation: The Plant's Ability to Maintain Optimal Sunlight

Science has ingrained the principle that plants require the sun to grow. However, not all plants require the same amount of sun in order to reproduce or grow. Certain types of plants have heliotropic characteristics to ensure they can initiate photosynthesis due to climatic factors. The most common types of heliotropic plants come from the legumes family; whereas the most known heliotropic flowers are Sunflowers as seen in Figure 10.1, Poppies, Marigolds, Daisies, and the Snow Buttercup [4]. Other commonly known plants that show heliotropic abilities are alfalfa and cotton [5]. Although, a distinction needs to be made between heliotropic plants and phototrophic plants which are closely related terms. Phototropism is a higher level function in which organism respond to a light stimulus. For example, when a potted plant is placed on a window sill, the plant will be stimulated to lean towards the window in order to obtain more sunlight and increase its growth capabilities. Heliotropic plants follow the direction of the sun throughout the day. Plants exhibiting heliotropic capabilities are not only stimulated by the sun, but physically track the sun's motion across the sky from east to west [6].

The first question tends to focus on how heliotropic plants can move without muscles. The easiest answer is that they have genes that work to an "internal" clock that corresponds with the sun's movement. Scientists at the University of California Davis, determined that genes stimulate growth on the west side of the stems during the evening hours when the sun is down in preparation of dawn. As a result, the heads/leaves of the plant orient east. When the sun rises, growth is directed to the eastern portion of the stems at a rate that correlates with the movement of the sun throughout the day. This growth rate is calibrated to a precision that enables the plants to "track" the sun to obtain the most amount of sunlight [7]. After the sun has set again, some heliotropic plants assume a random orientation; whereas others enable chemical reactions to return the leaf or flower back to the east facing orientation in preparation for dawn. The movement and gene stimulation can be attributed to the pulvinus or flexible sections of the plant that change the pressure of localized tissues by producing increased levels of potassium ions [8].

There have been numerous hypothesis as to why these plants have this capability ranging from offensive tactics to attract pollinators all the way to a polar opposite theory that attributes this mechanism as a sort of a self-defense mechanism to ensure its survival. While some of these hypotheses may contradict, scientists have reason to believe all the theories may be correct. That in fact this phenomenon is a benefit to not only the plant, but to all that come into direct and indirect contact with the plants. The three most common hypotheses will be discussed in the following paragraphs.

10.2.1 The Heating Hypothesis

This theory focuses on a mutualism relationship in which both pollinators and plants benefit by the heating of the sun. The heat energy absorbed by the plant enhances seed production. Generally, pollinators do not have the ability to generate their own heat and rely on the sun's heat to warm them. Therefore, heliotropic plants are attractive to these pollinators because they tend to be the warmest plants in any given habitat because of their optimal alignment with the sun at all day time hours. This warming effect provides the pollinators with a comfortable environment in which they can warm themselves and/or feed off the nectar. Pollination then occurs which leads to the production of seeds [9]. The pollinator attraction hypothesis is a direct reward for pollinators and the heliotropic plants [10].

10.2.2 The Growth Hypothesis

The growth hypothesis assumes that effective absorption of solar energy and the resulting rise in temperature has an effect on pollen germination and the growth of the pollen tube and seed production [11]. At first glance, this hypothesis seems similar to the heating mutualism theory; however, the growth hypothesis simply states that the plants have this ability for growth purposes only. This is not a mutualism capability in which nature developed to benefit both the pollinator and the plant. This hypothesis believes the pollinator role is attributed to evolution in which pollinators have learned to take advantage of this phenomenon. The heliotropic plants track the sun to grow as abundantly and rapidly as they can in areas in which the reproduction cycle is short or limited due to environmental conditions. This hypothesis is prevalent for heliotropic species in the arctic climates.

10.2.3 The Cooling Hypothesis

The cooling hypothesis focuses on protecting plants from being scorched by the sun in hot climates. The heliotropic plants adjusts its position in reference to the sun to avoid overheating. This thermal regulation mechanism of the leaves enables the plant to control the amount of solar radiation incident to any given leaf [12]. In the hotter environments, a short growing season has led to adaptations that allow the heliotropic plants to thrive by absorbing as much light as possible and also the ability to protect itself once its optimal thermal range has been exceeded. This defense mechanism has enabled heliotropic plants to cultivate an ideal reproduction climate in some of the harshest environmental conditions that are uninhabitable for most plant species who do not exhibit this phenomenon.

10.2.4 Benefits of Heliotropism

Regardless of the theory or hypothesis as to why plants have heliotropic abilities, it is a hybrid ability that takes advantage of all the symbiotic relationships in its environment. Heliotropism can be viewed as an evolutionary modification of the characteristics of a plant by manipulating its capabilities in order to thrive in any environmental condition. Heliotropism enables a plant to absorb more warmth and light. This then leads to a warm and welcoming environment for insects which leads to an increasing likelihood of pollination, reproduction, and seed germination. While at the same time, the opposite can be true. Heliotropism enables a plant to prevent overheating. Which will also lead to an increasing likelihood of pollination, reproduction, and seed germination [13].

Plants that face the sun reach higher internal temperatures and also retain water more rapidly on average than flowers that just face directly upward. The same can be said for flowers who face the sun versus flowers who orient away from the sun. Therefore, heliotropic plants are less sensitive to ambient temperature changes than non-tracking flowers because this ability enhances the plant's capacity to warm under cool conditions and heat up under cold conditions. This ability allows the plants to avoid heat or cold stresses and maintain energy to focus on photosynthesis. The synergistic effects of heliotropic plants enable it to adapt to various climates around the world [14].

A common and persistent theme to heliotropic plants is that they all thrive in harsh climates. These plants can do this through the use of their adaptive leaves/heads. The heliotropic movements regulate the amount of solar radiation incident on a leaf. Depending on the plant species or time of day this regulation may be maximizing or minimizing the amount of sunlight. On clear days, heliotropism can reduce total radiant energy on the leaf blade by 20-30%. Also, heliotropic plants can control the factors that enable photosynthesis which leads to an increased photosynthesis rate ranging from 29 to 42% [15]. Therefore, these movements have a profound impact on plant energy efficiency, leaf and plant temperature, water efficiency, and most importantly photosynthesis efficiency. The regulation of all these factors gives these plants an advantage in growth, seed production, and reproduction when compared to plants with stationary leaves [8].

10.3 Main Components and Factors

The main components related to heliotropic plants relate to their ability to follow the sunlight during the course of a day. When heliotropic plants are closely examined a few, specific factors will be discussed. The sun comes up and sets every day and plants, specifically the sunflower understands this process. Sunflowers prepare for the morning sunlight by facing east during the nighttime hours and following the sun

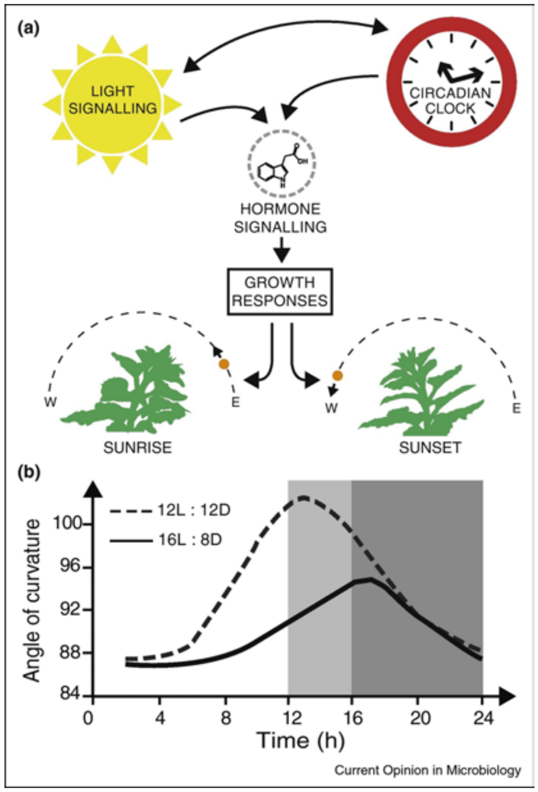

Figure 10.2: Sunflower growth affected by the circadian clock and sunlight [16].

throughout the day as it sets in the west. The second factor is phototropism. Phototropism is the process that helps a plant focus its leaves in the direction of sunlight. This focusing of the plant to the sunlight promotes additional photosynthesis.

The path that the Earth takes around the sun on its axis exposes the surface of the planet to repetitive changes in quality and quantity of the sun light received. This has created an environment where many plants attempt to receive all the available sunlight provided by the sun for photosynthesis and healthy growth. The natural environment responds to these cyclic changes with rhythms in biological activity driven by a molecular pacemaker called the circadian clock [16]. Circadian clocks, as seen in Figure 10.2, are signaling networks that enhance an organism's relationship with the rhythmic environment, such as daylight and night coming each day. The plant circadian clock influences a wide range of physiological and biochemical events, such as photosynthesis and the induction of flowering [17]. This clock helps prepare plants to receive all available energy resources to support plant growth and pollination.

An additional growth pathway for plants is phototropism, this is a process in which plants align their photosynthetic organs with the direction of incoming light. This occurs when plants receive a light stimulus that then trigger growth in the cells furthest away from the light source below. This far side growth encourages plants to bend towards the light source to increase photosynthesis and healthy growth.

Heliotropism, or solar tracking, is a more dynamic form of phototropism, this generally occurs in the upper portions of the plant [19], [20]. Heliotropism requires a moving light source as plants grown in greenhouses or growth chambers with consistent overhead lighting do not display heliotropic movement, indicating that the behavior is dependent on a dynamic, directional light source [21]. Heliotropism is generated by the combined action of light-signaling pathways and the circadian clock. These two actions working in parallel enhance the plant's performance in the natural environment. Sunflower stems exhibit this movement such that their new growth on top shifts from facing east at dawn to facing west at dusk as they track the sun's relative position [22], [23], [24]. These additional pollinators promote healthy plants. As a sunflower reaches full growth it no longer follows the sun during the daytime and it faces east permanently [22]. By facing east the full size sunflower provides the warmest flower to the pollinator without "following" the sun throughout the day.

10.4 Governing Physics and Parameters

The governing physics and biology parameters associated with the plant's ability to maintain optimal sunlight through heliotropism has been established through evolutional changes of the plant in order to thrive in harsh environments. A heliotropic response is a sequence of the following processes: reception of the directional light signal, signal transduction, transformation of the signal to a physiological response, and the production of directional growth response [25]. These heliotropic processes and parameters of the plant have taken advantage of fundamental laws of physics which can be attributed to five common physics curriculum subjects. These topics focus on pressure, osmosis, light, spatial orientation, and surface area. The collaboration of these principles into one phenomenon has enabled plants to maintain an optimal amount of sunlight for the photosynthesis process.

10.4.1 Pressure and Osmosis

Pressure: the continuous physical force exerted on or against an object by something in contact with it and is defined as force per unit area [26].

Osmosis: a process by which molecules of a solvent tend to pass through a semipermeable membrane from a less concentrated solution into a more concentrated one, thus equalizing the concentrations on each side of the membrane [26].

When discussing heliotropic plants, the type of pressure used to move the plants is called turgor pressure. Heliotropic plants use this law of physics through its pulvinus organ. As mentioned earlier, the pulvinus organ is located at the base of the leaf or at the head of a heliotropic flower. The red lines in Figure 10.3 point out the pulvinus portions of a plant.

As seen above, the pulvinus organ is a joint-like thickening at the base of a plant leaf or flower head that facilitates the physical movement of the plant. They consist of a cavity of vascular tissue within a flexible, bulky cylinder of thin-walled cells [27]. Pulvinar movement is caused by changes in pressure leading to a contraction or expansion of the vascular tissue located inside the joint. This vascular tissue can be seen as the pockets of tissue indicated in Figure 10.4.

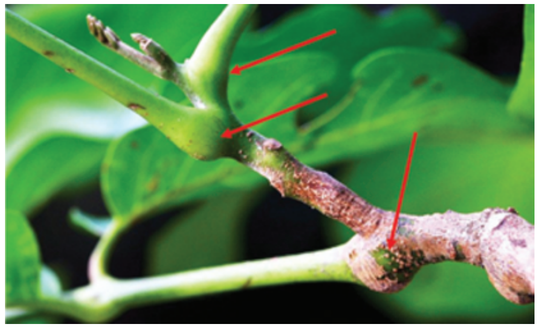

Figure 10.3: Pulvinus organs on a plant.

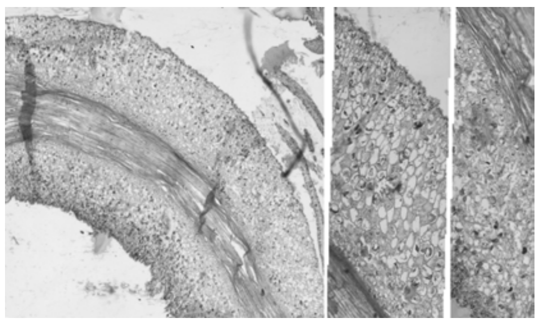

Figure 10.4: A depiction of the pulvinus organ and the plant's cell membrane [28].

The response is initiated when an increased amount of solute in the pulvinus decreases the water potential and triggers an efflux of potassium ions from the surrounding cells. This is followed by an efflux of water, resulting in a sudden change of turgor pressure in the cells of the pulvinus [28]. The process is a direct result of osmosis and can be seen in everyday processes like filtering water or the human's body's natural process of filtering blood [27]. Common examples of pulvinar movements include the night movement of legume leaves into a protective formation and the tracking of the sun by sunflowers throughout the day.

Turgor pressure can be envisioned as the internal pressure of a plant's cell wall depicted in Figure 10.5 below. Turgor pressure is a mechanism employed when the plant's plasma membrane is pushed against its cell walls. This pressure is caused by the flow of water from an area of low concentration outside the cell into the cell's cavity, which has a higher concentration [29].

The physical principle known as osmosis comes into play to cause the water to flow from one area of high water concentration and low solute to a low water concentration area and high solute. This process continues until the two areas have an equal ratio of solute to water. The cell's membrane permits the flow of water in and out of the cell but restricts the flow of solute.

Eventually, the cell's membrane is enlarged such that it pushes against the cell's

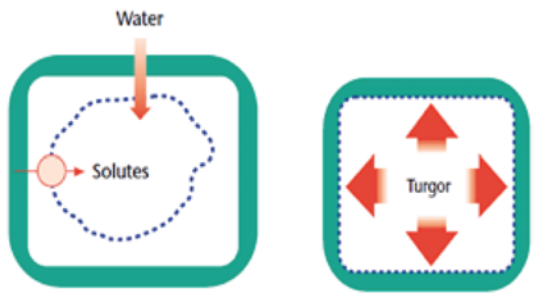

Figure 10.5: As water enters inside the cell wall indicated in blue through osmosis, the turgor pressure increases due to the cell's membrane enlargement [30].

wall. Changes in turgor pressure strongly depends on cell volume. The turgor pressure of heliotropic plants can be attributed to pressure seen in hydraulics and ratios seen in the osmosis process [31].

10.4.2 Light

Light: is defined as luminous, radiant energy in the form of electromagnetic radiation ranging in wavelength from 400 to 700 nm and propagated at a speed of 186,282 mi./sec, considered variously as a wave, corpuscular, or quantum phenomenon [26].

Light serves as the major energy resource to initiate the heliotropic process. Light's wavelengths trigger the heliotropic process through the perceived blue or red light by the photoreceptors near the major parallel veins. The photoreceptor molecules detect illumination and whether it is directed toward the tip or toward the base of the leaf. Whereas, the light perception by the pulvinus organ precludes signal transmission over a long distance. Thus, there are two different mechanisms for the detection of light direction in leaves: 1) a vein mechanism that senses light vectors 2) a pulvinar mechanism that senses light gradients [32].

Plants rely on several laws of physics in order to efficiently align the leaves to obtain the most/least amount of sunlight. Most heliotropic plants respond to the blue wavelength by aligning the leaves or flowers to an incident angle to the sun's wavelength. Whereas other plants whose goal is to protect itself from overheating will orient the leaves to reflect sunlight [33]. As seen in the Figure 10.6, the ray of light approaching the surface is known as the incident ray.

The ray of light that exits the surface is referred as the reflected ray. At the point of incidence, where the ray strikes the mirror, a normal line can be drawn perpendicular to the surface of the mirror. The normal line serves as the median angle between the incident ray and the reflected ray. The angle between the incident ray and the normal is known as the angle of incidence. The angle between the reflected ray and the normal is known as the angle of reflection [34].

As stated earlier, an important factor which could seem obvious is the fact the light source must be dynamic in order for plants to exhibit heliotropic behavior. Scientists determined this behavior indicates heliotropism is dependent on a dynamic

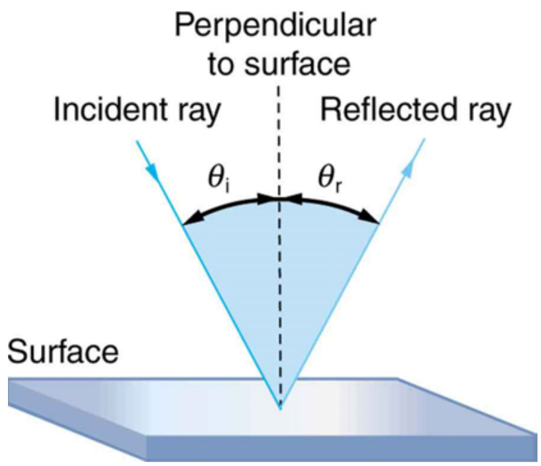

Figure 10.6: Laws of Reflection [34].

and directional light source [35].The Plants orient their leaves in respect to these laws based on the purpose they are aiming to achieve. If the goal is to cool the plant, the leaves will orient to the angle of reflection to reduce the heating and may orient several leaves to offer shade in an orientation to reflect the sun's rays and heat. If the goal is obtain the most amount of sunlight the plant will track the sun and orient its leaves in the angle of incidence throughout the day to maximize the photosynthesis process. During the day, the sun warms the plants as waves of sunlight are absorbed and the thermal energy excites atoms in its leaves, triggering photosynthesis and creating heating. Too little heat results in very slow growth, but excess heat can be destructive. Plants have evolved and adapted by producing leaves with varying degrees of reflectiveness. Dark leaves absorb the most energy from sunlight, whereas light colored leaves reflect excess sunlight [36]. The plant's ability to change the angle of its leaves can reduce the total radiant energy on the leaf blade by 20-30%. Therefore, these leaf movements have a large impact on leaf energy balance, leaf temperature, transpirational water loss, carbon gain through photosynthesis, and water use efficiency [37].

10.4.3 Spatial Orientation and Surface Area

Spatial Orientation: Defines the natural ability to maintain orientation and/or posture in relation to the surrounding environment (physical space) at rest and during motion [26].

Surface Area: measure of how much exposed area a solid object has, expressed in square units [26].

Plants use a combination of spatial orientation and the surface area of its leaves to ensure the maximum amount of sunlight can be absorbed or reflected through heliotropic movements. Up to now, the movement of individual leaves was analyzed. However, the spatial orientation and surface area of all the leaves in a plant's canopy has to analyzed to reflect the synergy of these aspects to form a systemized feature that enhances the plant's photosynthetic efficiency.

Figure 10.7: Spatial orientation of leaves in a Tree's canopy to minimize light interference or shade.

Scientists have determined that plants position its leaves so that each collects its share without interfering with any other leaf. This capability is achieved through multiple mechanisms of changing the posture of the leaves throughout the day as the sun moves across the sky [38]. Leaves can move in relation to each other on a non-interference basis by moving at greater and more varied amplitudes. Wide and ruffled blades prevent self-shading by spreading themselves apart and increasing their exposure to sunlight. This design allows the plant to control the amount of sun light it receives but also limit the amount of overheating. The leaves, through convective heat transfer, cool by wind blowing across the leaves [39].

If leaves overlap too much or are too closely spaced vertically, then the shading and light interference of the leaves will decrease the interception of the light rays. This will result in a decrease of photosynthetic efficiency. Conversely, if the arrangement of the leaves allow gaps in the canopy, then the photosynthetic efficiency will still decrease because the amount of sunlight will not be absorbed by the plant's leaves [40]. This arrangement can be seen in Figure10. 7.

Therefore, an equilibrium must be established between the amounts of space between each leaf in relation to each other. The shape of leaves also plays a big role in terms of the surface area. Curved shaped leaves offer small surface area for plants in hot climates. Whereas large leaves can capture as much sunlight as possible in areas in which the season is short. Thus, maximizing its photosynthetic efficiency in short seasons. To maximize cooling, some plants produce leaves with high surface area. Rough leaves have more surface area than smooth leaves. This provides more space for the transformation of liquid to vapor. As a result, there are greater cooling benefits due to the high humidity surrounding trees with rough leaves [41].

It is evident that the parameters associated with heliotropic plants relies heavily on the fundamental laws of physics and biology. The mastery of these laws has enabled the plant to tackle numerous stresses and climates. The heliotropic plant's ability to use pressure, osmosis, light, spatial orientation, and surface area to harness the sun's rays is indeed a phenomenon. The interaction of these elements and parameters, that when combined, produce a total effect that is greater than the sum of each of the individual leaf contributions. In effect, the plant has produced a redundancy to ensure its existence and reproduction. The duplication of all these critical components and functions as a system of efficient light absorbing antennas with the single intention of increasing its photosynthetic reliability has in a sense provided a backup or fail-safe to ensure system performance [42].

10.5 Describing the Physics

In a simplified manner, there are a few key concepts to grasp about how plants can and in fact do track sunlight. From the cycles of day and night to how the plant has the ability to attract additional pollinators by directing flowers and leaves towards a light source. The ability of nature to process sunlight into energy for the plant proves to be a complicated process. A simplified version of photosynthesis and heliotropism will be explored in the following sections.

10.5.1 Circadian Clock

The path that the Earth takes around the sun on its axis exposes the surface of the planet to repetitive changes in quality and quantity of the sun light received. This has created an environment where many plants attempt to receive all the available sunlight provided by the sun for photosynthesis and healthy growth [43]. The natural environment responds to these cyclic changes with rhythms in biological activity driven by a molecular pacemaker called the circadian clock [16]. Circadian clocks are signaling networks that enhance an organism's relationship with the rhythmic environment, such as daylight and night coming each day. The plant circadian clock influences a wide range of physiological and biochemical events, such as photosynthesis and the induction of flowering [17]. This clock helps prepare plants to receive all available energy resources to support plant growth and pollination [44], [45].

Experiments conducted by Dodd have demonstrated that the circadian clock allows plants to increase photosynthesis. This occurs from the correct anticipation of dawn and dusk, and synchronization of the synthesis of light-harvesting complex proteins and chlorophyll [43]. Incorrect matching of natural rhythms to environmental rhythms reduced leaf chlorophyll content, reduced assimilation, reduced growth, and increased mortality [43]. Optimization of these parameters by circadian resonance has allowed plants to survive nature's evolution.

10.5.2 Photosynthesis

The word photosynthesis can be separated into two smaller words, "photo" which means light and "synthesis" which means putting things together. Plants require carbon dioxide (CO_2), water (H_2O) and sunlight to produce their food. The plants put these together with sunlight to produce food and oxygen. Plants use this food for healthy growth, flowering and even producing fruit. Carbon dioxide from the air passes through small openings in the leaves called stomata. This carbon dioxide is combined with water absorbed by the roots of the plant and passes through vessels in the stem on its way to the leaves. Photosynthesis occurs in the cells of each leaf on the plant. Inside each cell there are small structures called chloroplasts. Each chloroplast contains a green chemical called chlorophyll which gives leaves their green color and absorbs the sun's energy. Eq. (1) lays out what this process likes like in equation form.

$$\underset{\text{Carbon Dioxide}}{\boldsymbol{6CO_2}} + \underset{\text{Water}}{\boldsymbol{6H_2O}} \xrightarrow{\text{Sunlight}} \underset{\text{Glucose}}{\boldsymbol{C_6H_{12}O_6}} + \underset{\text{Oxygen}}{\boldsymbol{6O_2}} \tag{10.1}$$

Photosynthesis uses the energy collected from the sun by the chlorophyll to split water molecules into hydrogen and oxygen. The remaining oxygen is then released by the leaves into the atmosphere. Some of the glucose that is created by this process is used to provide energy for growth and development of the plant while the rest is stored in leaves, roots or fruits for later use by the plants.

10.5.3 Turgor Pressure

Turgor pressure is critical to plant function as plants work like hydraulic machines moving fluids around. Turgor pressure helps with growth, transport and movement of fluids within the plant [44]. Plant cells generate hydrostatic pressures known as turgor pressure. The plants regulation of turgor pressure is the result of a plant's response to changes in nature, such as additional sunlight or temperature changes. A breakdown in this process of regulating the cell pressure reduces the performance of a plant. This breakdown occurs during stressful times of growth, such as limited water supply or extreme temperatures.

A major factor determining the magnitude of the turgor pressure is the total number of solutes accumulated inside the protoplast; the osmotic pressure of the cell contents ($\boldsymbol{\pi}$) provides a measure of this. The osmotic ($\boldsymbol{\pi}$) and turgor pressure (P) of a cell are conveniently combined in the term water potential, which is a measure of the energy state of the water at any point [44]. Pritchard describes this equation as shown below in Eq. (2).

$$\boldsymbol{\Psi_w = P - \pi} \tag{10.2}$$

The difference in water pressure between the cell and its environment are the driving force that determine if the cell takes on additional water. Water travels from a higher to a lower water potential to reach equilibrium. There are a number of factors can reduce turgor pressure below what is predicted but that is beyond what will be discussed here.

Cell extension drives nearly all plant growth and occurs because turgor pressure stretches the cell wall [46]. These forces generated by the cells can be very large, as can be seen by a plant's root system. A plant's root system can force its roots through compacted soil full of rocks and debris. Turgor pressure also provides a hydrostatic skeleton to support leaves and stems. This is evident when a plant wilts due to lack of water. Although plants are planted in one spot in the ground they can still manipulate themselves to gain a better incident angle with the sun rays. A plant's leaves and flowers move to track the sun, maximizing photosynthesis and pollination. In more extreme environments leaves turn away from the sun to prevent overheating. Such movements are caused by reversible variation in turgor on different sides of the stem.

10.5.4 Heliotropism

As stated throughout the paper, Heliotropism is a more dynamic form of phototropism, this generally occurs in the upper portions of the plant as it usually requires new growth to provide the directional change to “track” the sun. Heliotropism in the common sunflower is generated by the combined action of light-signaling pathways and the circadian clock. These two actions working in parallel enhance the plant’s performance in the natural environment. Plants that experience heliotropism have been shown to provide about 9.5% increase in photosynthesis versus a stationary leaf [47]. This additional sunlight provides additional resources to the plant to promote healthy growth. Heliotropism is possible due to the growth of cells in a plant that are furthest from the light source. This growth promotes a directional growth towards the light source. Phototropism and heliotropism are complex biological responses involving interactions of multiple photoreceptors and multiple signaling pathways that together combine to produce a growth gradient on the shady side of a plant [48].

According to Shell, the ability of a plant to receive sunlight is given by the variable I, irradiance. This is the area of a leaf that is normal to the sun’s rays. The larger this area the more significant the amount of sunlight the plant can process and is displayed as Eq. (3) [49].

$$\boldsymbol{I = f_i(A)C_i} \tag{10.3}$$

Where $\boldsymbol{f_i(A)}$ is the fraction of the total leaf area for a given plant and $\boldsymbol{C_i}$ of $\boldsymbol{\cos\theta}$ being the angle between the leaf-normal and the sun’s beam. By using this calculation, it has been shown that the sunflower will intercept significantly more radiation than could be expected for a random leaf distribution. A random leaf distribution would be a distribution that does not follow any kind of process or sun tracking [49].

10.6 Experiment and Analysis

There are a few specific areas that could be focused in on for additional research. The areas of interest are listed below.

- Leaf Area Index
- Incident Angle / PFFD Transmission
- Leaf Temperature
- Turgor Pressure

10.6.1 Leaf area Index

Leaf area index can be calculated as seen below or it can be measured using a ceptometer. If this is measured, a reading can be taken in direct sunlight and compared to a reading taken directly under the canopy. These measurements can determine the health of a plant’s canopy and be used as comparisons against past measurements. These measurements can also be used to determine optimal plant spacing and row directions during planting. This would be critical information to define in an effort to replicate this type of design in the engineering realm.

Thermal time or growth degree day (GDD) controls the amount of growth permitted by the plant. This comes down to the more sunlight the plant receives the more it can grow and produce. Therefore, testing the amount of sunlight each leaf receives or trying to optimize the amount of sunlight to each leaf will prove to be beneficial in this application. There is a balance between leaf density versus the size of the leaf. As the leaf gets larger the more of a shadow it will cast on the other leaves, therefore reducing photosynthesis in the other areas of the plant. Below are the calculations to determine the leaf area index for sunflowers. Growth degree (GD) is calculated from Tb and Tc being defined as base temperature and critical temperature respectively [50].

$$\begin{aligned} \boldsymbol{GD} &= \boldsymbol{T_b} \quad \text{if} \quad \boldsymbol{T < Tb} \\ \boldsymbol{GD} &= \boldsymbol{T - T_b} \quad \text{if} \quad \boldsymbol{T > Tb} \\ \boldsymbol{GD} &= \boldsymbol{T_c} \quad \text{if} \quad \boldsymbol{GD > Tc} \end{aligned}$$

T is average daily temperature and growth degree day (GDD) was calculated by accumulating GD after the plant emerges from the surface. During the initial leaf growth rate, from emergence to the end of the vegetative stage, is referred to the period of fast linear growth during which the LAI increases at a constant rate and calculated by below in Eq. (4) [50]:

$$\begin{aligned} \boldsymbol{LAI(i)} &= \boldsymbol{(LAI_{max}/GDD1) * (GDD(i))} \\ &\quad \text{if} \quad \boldsymbol{GDD(i) \leq GDD1} \end{aligned} \tag{10.4}$$

Where $\boldsymbol{LAI_{max}}$ equals the $\boldsymbol{LAI}$ at maximum growth rate and $\boldsymbol{GDD1}$ represents the accumulated thermal time from emergence till the end of the initial leaf growth rate [50].

The leaf area index in its simplest form is the amount of leaf area divided by the amount of ground surface area. This is a dimensionless number that can help gauge the health of a broad leaf plant's canopy.

10.6.2 Incident Angle / Photosynthetic Photon Flux Density

Incident angle is closely related to heliotropism in the fact that the plant follows the sun in an attempt to receive additional sunlight. The plant is trying to maintain a perpendicular angle to sunlight rays. Plants that experience heliotropism have been shown to provide an increase in photosynthesis versus a stationary leaf. This additional sunlight provides additional resources to the plant to promote healthy growth. Heliotropism is possible due to the growth of cells in a plant that are furthest from the light source. Phototropism and heliotropism are complex biological responses involving interactions of multiple photoreceptors and multiple signaling pathways that together combine to produce a growth gradient on the shady side of a plant [48].

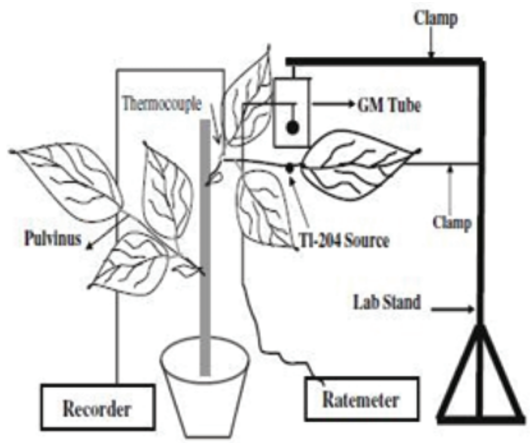

Figure 10.8: Setup to test leaf temperature [52].

According to Shell, the ability of a plant to receive sunlight is given by the variable I, irradiance. This is calculated by the area of a leaf that is normal to the sun's rays. The larger this area the more significant the amount of sunlight the plant can use to process carbon dioxide and water. This calculation is directly based on the incident angle of the leaf against the sun's rays.

The verification of this comes in the form of photosynthetic photon flux density (PPFD). This is the measurement of light (photons) that reaches the leaf. This measurement can be verified and tested with a ceptometer [51].

10.6.3 Leaf Temperature

Leaf temperature has an effect on how the plant behaves in relation to the sun. For example, a leaf that gets warmer than necessary will turn away from the sun to protect itself. This optimal temperature should be examined to help understand how nature solves this problem. This temperature safety feature that plants exhibit could be implemented in a slightly different way to provide safety to solar panels should a hail storm or extreme weather be coming. Understanding the temperature at which this happens on a plant will provide the details of how early this process starts and when the plant knows its time to start protecting itself. The test fixture pictured below in Figure 10.8 is how a test setup to measure the leaf temperature would be implemented.

10.7 Feasibility, Limitations, and Advantages

10.7.1 Feasibility

A team of four decision makers (3 Engineers, and 1 Biologist) were asked to complete the exercise using the Stochastic Multicriteria Acceptability Analysis (SMAA). The

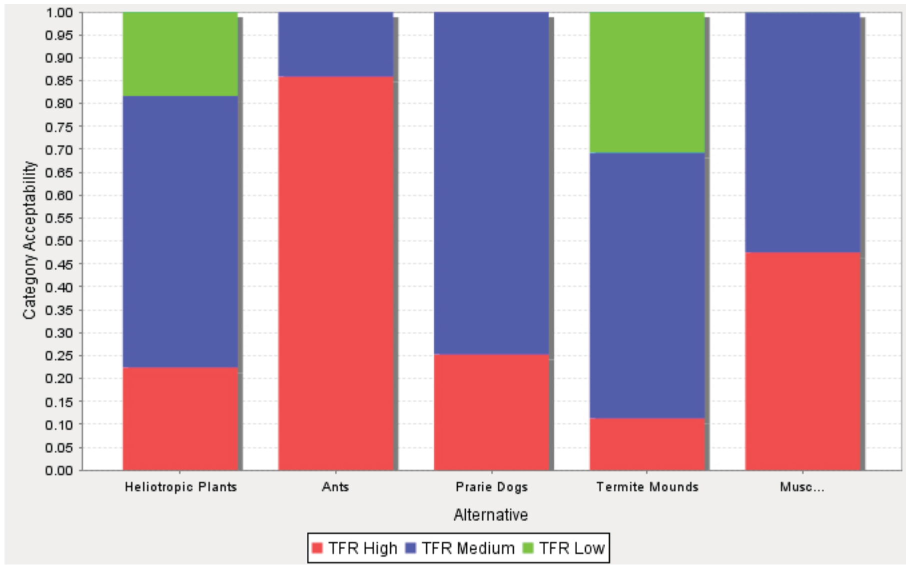

Figure 10.9: SMAA Results [53].

purpose of this exercise was to use SMAA with a set of criteria, derived from Biologically Inspired Design (BID), to assist multi-disciplinary decision makers evaluate biology-to-engineering transfer risk for candidate-design analogs. This framework guides decision makers to a low-risk choice by using externally valid predictors of design transfer risk [1]. The team decided to increase the number of decision makers to have a differing perspective that included considerations from a decision maker who was not an engineer. Also, the increase of decision makers allowed a stabilization of the standard deviation so that the results would not be hypersensitive to differing scores from 4 decision makers versus just two decision makers. The exercise utilized the design problem with the candidates and was completed in 3 rounds of scoring. The results are included for each round [53].The results from the analysis are shown below in Figure 10.9.

The first and second round did not provide a definitive solution as no candidate was ranked over 0.1 in the TFR Low category. After each round, a clarification and discussion took place to help the decision makers align on a common thought process when analyzing the criteria and the ranking process. In the third round, two candidates emerged as the lowest risk options. The termite mounds and heliotropic plants proved to be the lowest design transfer risk to the engineering domain [53]. This analysis enabled us to pursue further.

10.7.2 Limitations: Cost and Expertise

The current team analyzing this phenomenon, with the intent of transferring this biological phenomenon to the engineering domain, is restricted by its disciplines and formal education in this broad and extensive scientific field. Biology is a complex field when trying to learn the underlying principles and assess if the biological solution is better than the existing ones available in today's market and technology. The ability to describe the complexity of this phenomenon is dependent on the approach. Each field of science and engineering defines and views complexity in different ways in the absence of a unifying concept or general complexity theory [54]. No one answer is correct and no one answer is wrong. However, a plant biologist would be able to uncover the most intricate components and processes to ensure no stone is left unturned. The expert would be able to offer additional biological principles that translate into the technological realm.

As of right now, the team consists of a mechanical and electrical engineer. In order to successfully implement a biomimetic engineering solution, a transdisciplinary perspective must be taken to ensure all aspects of the phenomenon are questioned, tested, and thoroughly examined. When solutions to complex problems are purposed, there are many facets of the solution that must be considered. Many times, these solutions must be considered through a transdisciplinary lens to examine the problem fully. The objective of transdisciplinary is to understand the present world, in all of its complexities, instead of focusing on one part of it [54]. While many solutions to complex problems have yet to satisfy all stakeholders, improved processes have been added to remedy the problems [55]. A complex problem that has not been addressed through transdisciplinary research and collaboration from all disciplines involved will produce a less than optimal solution [56].

Additionally, this biomimicry project would require the assistance of a statistician. One who would direct and frame the experiment and analysis portion of the project. The contribution of the statistical expert would focus on selecting and implementing the optimal analytic strategy and procedures for the data analysis of the experiments. Obtaining this resource would assist the team in collecting, inputting, and managing the data. Also, an expert would know the available software packages and tools that may be able to collaborate results, distributions, and theories. Understanding the various advanced statistical tests and models can correlate theories and conclusive evidence that may lead to an engineering innovation based on the behavior of heliotropic plants.

The cost to perform this research would be quite expensive due to our lack of statistical expertise. The experiment and analysis portion of our project focuses heavily on physical testing of the phenomenon and its processes. Utilizing simulations that could model the components/processes of the system and/or the phenomenon would greatly decrease the cost as well as offer a well-rounded analysis that could cover abundant iterations of the experiment. A cost-effective method in which the experiments can sample from the population with reasonable computational cost estimates based on a Monte Carlo Method would drastically improve the depth and robustness of the analysis and results while at the same time provide a path in achieving data with a high confidence interval [3].

10.7.3 Advantages: Applicability of Circadian Clocks

The applicability of circadian rhythms and clocks make this biomimicry project appealing and advantageous due to the immeasurable applications tied to circadian clocks. As mentioned earlier, circadian clocks have been traced to mammals, plants, fungi, bacteria and microorganisms and have a direct impact on each organism's health and behavior. Most people refer to the circadian clock as the biological or internal clock. Circadian clocks can be affected by natural and artificial light sources

Figure 10.10: SMIT Solar ivy product.

from the environment that cue influencing circadian rhythms to turn on or turn off genes that control an organism's internal clocks. For instance, the brain, kidney, liver, and hormonal system contain circadian clocks that must stay in sync in order to ensure efficient and healthy bodily functions in accordance with the time of day [57]. As a result of this, circadian synchronization within the cell and between organ systems is critical to health and well-being, and any breakdown of this time-based system can lead to harmful mental or physical conditions because circadian rhythms influence sleep-wake cycles, hormone release, body temperature and other important bodily functions. The interruption of this internal synchronization can lead to sleep disorders, obesity, diabetes, depression, bipolar disorder and seasonal affective disorder [57], [58].There are at least 15 genes that scientists believe make up the inner-makings of the circadian clock mechanism. Due to the variation of genetics from one person to the next, these components can result in profound differences in circadian clocks from person to person. This explains why some people are early birds and others are night owls [59]. Therefore, understanding how heliotropic plants correlate their movement to the circadian clock could offer insight to innovative applications or solutions in any or all of the following fields: medical, biomedical, biology, infectious diseases, pharmaceutical, and many more.

10.7.4 Emerging Technologies

1) Solar Cells Mimicking Photosynthesis

The emergence of existing technologies associated with Photosynthesis, Turgor Pressure, and Heliotropism make this topic advantageous to transdisciplinary and biomimetic engineers. Take for instance photosynthesis and its intended purpose of harvesting power from sunlight. Engineers have taken advantage of the photosynthesis phenomenon by replicating the harvesting of energy through the use of solar cells to produce electrical energy for humans. An extensive literature and market research of all the available technologies and products focused on solar cells led to the discovery of a solar cell design that utilizes the biological properties of the Ivy Plant. A company known as SMIT (Sustainably Minded Interactive Technology) designed their solar cells, as seen in Figure 10.10, to mimic the ivy plants by using Photovoltaic principles to convert wind and solar energy into electrical energy. Each 4 foot by 7 foot strip of the ivy leaves can generate up to 85 Watts of solar power.

This renewable energy will reduce heating and cooling costs while at the same

Figure 10.11: Residents view of the SMIT solar ivy product.

time offer aesthetic and shading benefits to the structure [60]. The solar ivy also solves the major issue of non-aesthetic solar cells that take up large footprints of a building's roof. As seen in Figure 10.11, this product addresses this issue by utilizing a solution that can be installed on all the vertical sides of the structure that at the same time is aesthetically pleasing to the inhabitants of the building.

In addition to Photovoltaic Solar cells is another emerging solar cell technology focused on a dye-sensitized solar cell. Dyesol has emerged at the forefront of this developing solar cell technology and market. The dye solar cell, as seen in Figure 10.12, is a low-cost alternative solar cell that is based on a semiconductor formed between a photo-sensitized anode and electrolyte. Compared to conventional silicon based photovoltaic technology, Dyesol's technology has lower cost and produces electricity more efficiently even in low light conditions and can be directly incorporated into buildings by replacing conventional glass panels rather than taking up roof or extra land area [61].

Dyesol's latest product is the Perovskite solar cell which has a potential impact for the future of renewable energy because it is easy to produce and so flexible that it can be sprayed or painted on varying surfaces. Conventional Photovoltaic solar cells have peaked in regards to power conversion efficiency at a level of 25% for the last 15 years. Perovskite on the other hand is expected to reach the 30% efficiency mark within the next three years. This technology is already accredited to the current international standard IEC61646, which conducts temperature tests at 85 degrees Celsius for over a 1,000 hour period, in which solar cells cannot degrade in performance by any more than 10% [62].

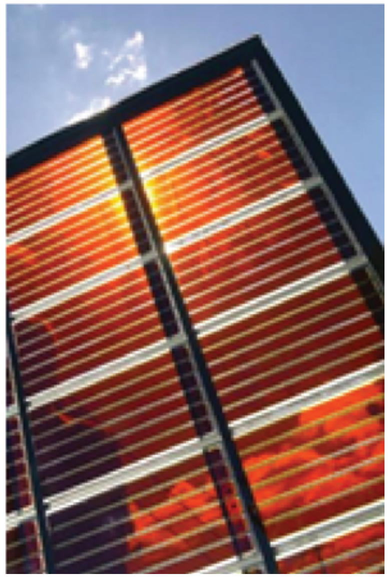

Figure 10.12: Dye solar cell.

2) Water Filtration Mimicking Heliotropic Cell Membranes

In terms of Turgor Pressure and Osmosis, an emerging technology focused on water filtering relies on the fundamental laws discussed earlier in this paper. We can recall that turgor pressure relies on the osmosis process to transfer liquids across the plant membrane to achieve a desired level or equilibrium for the plant's pulvinar movement in order to track the sun. The Aquaporin Company has used biomimicry to mimic the cell's ability to transport water back and forth across membranes by way of a membrane cha" much like osmosis while at the same time filtering out particles or ions that are not particular to water [63]. This innovation has offered a new filtration solution in both a forward and reverse Osmosis process that can be employed in industrial and household applications. Discovery of the aquaporins has provided the explanation for selective transport of water across the plasma membranes of cells without allowing protons to pass. The Aquaporin Forward Osmosis (FO), as seen in Figure 10.13, offers an energy efficient product that can be applied to difficult wastewater streams.

The FO process uses only the osmotic pressure difference between a feed water stream and the draw solution as a driving force. The Reverse Osmosis (RO) product, as seen in Figure 10.14, processes polluted water into drinkable or reusable water.

The Aquaporin technology allows RO membranes to have both improved water flux and higher rejection rates. Aquaporin is in the process of developing solutions for brackish water and seawater [64].

Figure 10.13: Aquaporin forward osmosis product.

Figure 10.14: Aquaporin reverse osmosis product.

10.8 Conclusion

Irrespective of the limitations of our team, the transfer risk computed using the SMAA Tool indicated there is a low likelihood of risk in transferring this biological phenomena to the engineering domain. The Biomimetic Engineering goal is to create a product or process that can enhance society's capabilities. Using this approach to innovate a sustainable solution mimicking the plant's ability to maintain optimal sunlight through heliotropism to maximize the photosynthesis process would solve an unquantifiable number of current and future global issues.

The purpose of this paper was to offer an understanding of how plants are induced by sunlight as well as the long-term possibility of replicating this phenomenon for human purposes. All the questions presented in the introduction of this paper has led us to the fact that there are answers and solutions to the question, "Can the plant's heliotropism principles be translated by Biomimetic engineering to innovate or improve upon available technologies/strategies employed to harvest renewable energy?" By introducing a Biomimetic Engineering analysis of the plants' ability to maintain optimal sunlight in order to maximize the photosynthesis process, we have covered complex processes and parameters in multiple scientific and engineering subjects. The thorough analyzation provided in this paper covering the mechanics, physics, and features associated with heliotropism has led us to the conclusion that this phenomenon can be transferred to the engineering domain in a number of various applications and fields. An engineering replication of this biological phenomenon would ensure an innovative approach that would positively impact crop production, energy resources, water resources, medical/pharmaceutical solutions, pollution, energy production, and most importantly the lives of humans and organisms whose current long-term sustainability is often apprehensively analyzed due to the dwindling options of food and energy.

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CHAPTER 11

A Transdisciplinary Approach to Unemployment In the United States' Petroleum Industry

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Unemployment in the petroleum industry is a complex issue with social implications, such as unemployment, poverty, and economic deprivation. With the industry supporting 9 million jobs within the United States alone, it can have far reaching impacts for the whole economy. Approaching this issue from a Transdisciplinary perspective, allows for an inherently holistic view of both the problem and solution spaces.
Keywords*:* Petroleum Industry, Transdisciplinary, Unemployment.

11.1 Introduction

The petroleum industry, often referred to as the oil and gas industry, is present in all fifty states and accounts for a large share the United States (U.S.) work force and gross domestic product (GDP). When discussing the petroleum industry, this includes exploration, extraction, refining, transport, and marketing for petroleum products. According the American Petroleum Institute, in 2011, the petroleum industry employed 5.6 percent of the United States workforce, and accounted for 8 percent of the national GDP [1]. With such strong ties to the United States economy, a large change in the employment rate for petroleum industry has the ability to impact the overall United States unemployment rate. If the petroleum industry was stable, this might not be of much concern, but history has shown it to be a cyclic industry.

Looking at the extraction area of the petroleum industry alone, it is easy to see the impact of these cyclic swings. At its height in 1981, oil and gas extraction accounted for 4.3 percent of the United States GDP, but by 1999 had declined to a mere 0.6 percent [2]. In 2011, when new advances led to the shale boom, it rose to 1.6 percent of the GDP, but dropped to only 172,400 individuals (0.1 percent of the work force) by the end of 2016 [3].

While the petroleum industry has historically experienced cyclic boom and bust swings, overall it has been slowly declining. This all results in increased unemployment within the United States. An economy with a high unemployment rate is typically in a recession, and is not considered healthy. A 2014 Gallup poll found unemployment was the number one concern amongst the U.S population [4]. Unemployment is a problem that can have far reaching effects for any society including poverty and economic deprivation. Studies have found that unemployment can have effects at the individual and community levels. An individual may suffer from not only poverty, but also mental and physical health issues, including depression and increased mortality, and even detrimental changes to family relationships [5]. Given the known negative effects of unemployment for both the individual and the economy as a whole, unemployment is a metric many governments track and try to influence.

11.2 Transdisciplinary Approach

There exist several tools in the current workspace of large scale or complex problem solving, specifically designed to enhance the value of, and reduce the time synthesizing, the potential solution set for resolving complex and large scale problems. The strategies which see the most widespread use in this space today include the multidisciplinary approach, the interdisciplinary approach, and the transdisciplinary approach. More commonly used in engineering environments today is that of the multidisciplinary approach. In this approach, experts within singular domains come together in a working group, with the goal to come up with an approach to understanding, handling, or solving a complex issue. The key to keeping this multidisciplinary lies in the way that the experts, with the domain knowledge of the respective fields involved, confront the issues. In a multidisciplinary environment, team members utilize their skillsets autonomously as a means to come up with domain specific solutions. Once results for each respective expert have been found, the synthesis of the solution space occurs when all experts come together with their individual ideas to share, and find out if there are contradictory findings. While this method has been adapted for use, with the intent to greatly accelerate learning in developing areas, where traditional methods for educational divestiture of knowledge still use frame works devised in previous era's solely due to the previously isolated nature of such locations [6], the process involved for multidisciplinary discussion becomes increasingly bogged down through multiple iterations during the synthesis phase. When domain knowledge experts come together with their isolated solutions, the discovery of contradictory evidence leads to iterative isolated recursions through the multidisciplinary process, meeting and evaluating until a solution is finally arrived at. While this specific methodology works in a modern day, highly evaluative environment [7], the impact on synthesis when bound by time becomes an increasingly glaring problem that has to be accounted for.

The second commonly used strategy, interdisciplinary evaluation, seeks to bypass the issue of iterative group comparison from single knowledge experts meeting to find contradictory results by implementing collaborative approaches for the synthesis of problem areas. Interdisciplinary approaches within academia have seen rapid success in tunneling through the artificial constraints that a standard multidisciplinary approach has inherent within its own structure [8]. While both multidisciplinary and interdisciplinary approaches have applicability within their academic fields of

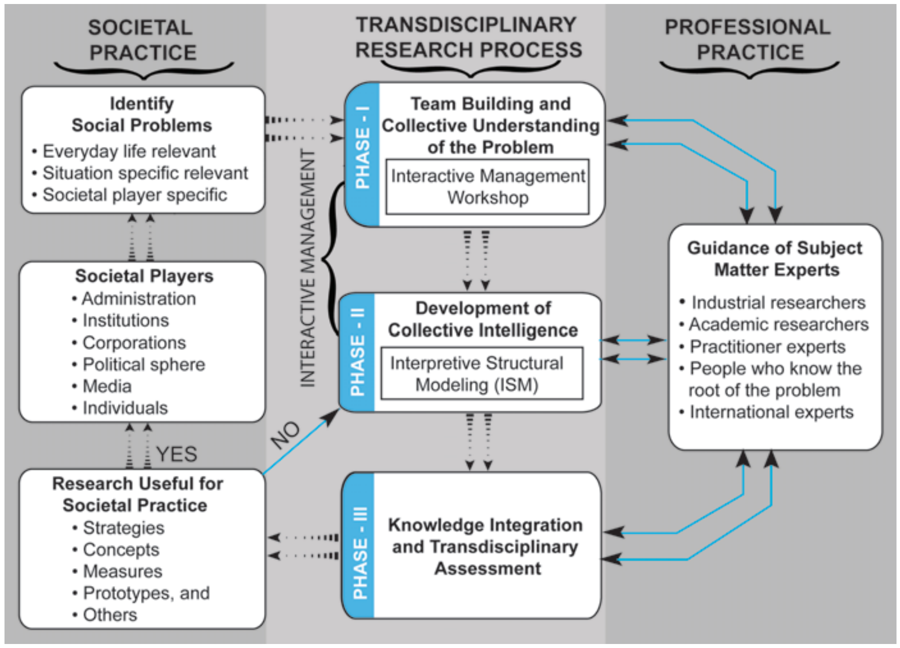

Figure 11.1: Transdisciplinary research process flow [10].

study, the application of these processes to real world issues, with temporal, fiscal, and political restraints are less than optimal.

The transdisciplinary approach presents as a method to integrate both classically trained, education based subject matter experts along with externally knowledgeable experts. This approach allows for the mapping of the transdisciplinary framework onto problems with effects found in both civil and academic areas, with specificity in the domain, where those areas transcend their boundaries and intermingle. When transdisciplinary tools are utilized in this manner, the benefits of having both academically collaborative research, as well as industry specific expertise allow the synthesis of the potential solution set to occur more rapidly, with more robust solutions [9]. Based on this, the transdisciplinary approach is the selected approach for evaluating the factors involved in unemployment within the U.S Petroleum industry.

11.3 Influential Factors

There are a number of factors which can impact unemployment in the petroleum industry. The basis of evaluation for which, will review the key elements of the process involved in performing Transdisciplinary research. Namely, that there are three primary phases: Phase 1 – Team Building and Collective Understanding of the Problem, Phase 2 – Development of Transdisciplinary (TD) Collective Intelligence and Phase 3 – Knowledge Integration and Transdisciplinary Assessment (See Figure 11.1). In Section 3, we focus on Phase 1 of the transdisciplinary Research Process while detailing the interactions within the "Professional Practice" domain through the use of the Kano style survey. In this phase of the research, our team touches on the concepts of Interactive Management, Collective Intelligence and the use of TD Generic Tools (e.g., Nominal Group Technique (NGT)). The use of each of these three aspects of the Transdisciplinary Methodology useful for Societal Problem Solving (SPS) offers the best opportunity for positive results from the research efforts.

An Interactive Management Workshop was conducted in order to engage in team building activities and come to a collective understanding of the problem. The Interactive Management Workshop included members of the research team, education professionals, working professionals, and researchers in related fields. This group conducted brainstorming activities and documented the possible factors for unemployment in the petroleum industry in the U.S., as a first step to model the relationships of these factors.

As the research team had decided to utilize Interpretive Structural Modeling (See Section 4 below) for further evaluation of the factors, it followed that the Nominal Group Technique (NGT) would be an appropriate method to generate ideas for defining a set of factors for the research. The five basic steps of the NGT process are given as:

1. Clarification of a trigger question,
2. Silent generation of ideas in writing by each group members,
3. roundrobin recording of the ideas,
4. Ongoing discussion of each idea for clarification and editing, and,
5. Voting to obtain a preliminary ranking of the ideas in terms of significance [10].

As the original list of potential factors was developed, it included the following loosely defined and ill organized set of ideas regarding the potential factors for unemployment in the Petroleum Industry: availability of new fields for exploration, the emergence of new technology (e.g., fracking), issues with lease/land Management agreements between companies and land owners, the market share & competing technologies, the effect of green energy, the impact of the coal industry, job market consistency for individuals, profit margins for oil & gas companies, the price of oil, international supply/demand of petroleum, Organization of the Petroleum Exporting Countries (OPEC) output rates, international demand, exploration and production costs, automation technology, research and development (R&D) activity levels, front end engineering design (FEED) activity levels, policy & regulations over the petroleum industry, export tariffs, domestic social issues, environmental concerns, individual employee adaptability (such as personal willingness to relocate/move family), and education levels/skill levels.

Although the initial efforts of the Transdisciplinary (TD) team brought about good discussion, the team needed guidance from subject matter experts in the petroleum industry. As part of a complete TD Team, the Issue experts were need to augment the individuals which already covered the structural modelers and stakeholders. The TD team reached out to an expert in the Petroleum Industry that could help guide the TD Team in reducing the initial list and preparing for a larger engagement with additional subject matter experts in the petroleum industry.

As a result of the involvement of a 38-year veteran and former Vice President within the Petroleum Industry, a reduced and more concise list of potential factors was created. The list included Cost of Labor and Benefits (Taxes, Insurance, Pension, etc.), Social Issues (e.g., Climate Change Activism), Individual Employee's Education/Tradecraft Skill Level, Regional Job Market Competition in the Energy Sector (Wind, Solar, Coal, etc.), U.S. Regulations (EPA, OSHA, FERC, etc.), Lease Operating Expenses, Price of Oil, International Tariffs on U.S. Oil & Gas Exports, Increase in the Use of Automation Technology, OPEC production and output amounts, International Political Climate and Stability, Individual Employee's Adaptability (e.g., willingness to relocate), and U.S. Import/Export Tariffs.

This resulting list of factors (above) became the basis for a formal Kano Survey (shown in in Appendix A). This survey was sent to more than fifteen (15) subject matter experts that serve as decision makers in the Petroleum Industry. The Kano Survey was utilized as a mechanism to reach out to Issue Experts and devise a final list of factors potentially linked to unemployment in the Petroleum Industry from which the TD Team could move to Phase II and Phase III of the Transdisciplinary Research Process (see Figure 11.1 [10]). The Kano Survey questionnaire, Kano Survey results are found as part of the Appendix in Figures A-1 and A-2.

As a result of the inputs received from Issue Experts and the Kano survey, the list of factors was reduced to eight (8) for further research. These top eight factors included Lease Operating Expenses, Cost of Labor and Benefits (Taxes, Insurance, Pension, etc.), Increase in the Use of Automation Technology, Price of Oil, International Tariffs on U.S. Oil & Gas Exports, U.S. Regulations (EPA, OSHA, FERC, etc.), Individual Employee's Education/Tradecraft Skill Level, and OPEC production and output amounts. Social Issues, although not identified by the experts in the Kano survey as a "must" for being included as part of the research, was maintained as a factor for additional research based on the input from the entire TD team. Furthermore, the OPEC production and output amounts factor is consolidated into the "Price of Oil" factor based on Issue Expert notations and inputs upon review of the Kano survey results.

The following section will discuss these eight factors in more detail so that the interactions between the factors are better understood in an effort to apply Interpretive Structural Modeling (ISM) techniques. Beyond defining each factor, the magnitude of each factor's impact is discussed as well as if and how it impacts the other influential factors.

11.3.1 Automation Technology Increases

Lease operating expenses, or LOE, are highly common within the petroleum industry. Costs such as these are considered upstream costs, which oil and gas companies lump in with capital costs. LOE costs are largely affected by the cost of production and maintenance per location, and in some cases can act as one of the precursor cost evaluation objects that lend weight to decisions on whether to begin operating, or retain, shutter, or outright eliminate existing operations. A study [11] performed by The Energy Industry Administration (EIA), found that LOE had a large impact on the viability of sites for petroleum related production. One specific evaluation used as a litmus for this estimation, is the Eagle Ford Region, an onshore play (land based oil rich area) located in Texas. Typical LOE costs include rig related costs; that is, costs directly affected by rig day rates, mud use, the cost of fuel, the cost of land, all of which are directly related to larger market conditions, as well as total drilling activity.

These costs are separate from other factors, such as casing, and drilling and

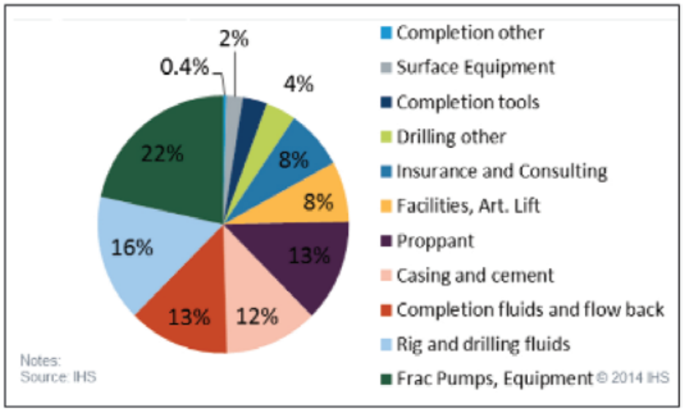

Figure 11.2: Eagle Ford Capex Breakdown [11].

well design and implementation costs. The total combined cost of the Eagle Ford Capex (EFC) Location can be found here, in Figure 11.2 [11]. From the entirety of these costs, the EFC LOE represents 12-19% of total capital operating expenses. These expenses, are very inelastic, in comparison to market pricing of petrol products, making the highly rigid LOE costs very sensitive to market fluctuation. One additional factor for consideration, with regard to automation technology increases is the pool of adequately skilled, educated labor. With factors such as globalization, and technological increases, coupled with current corporate trends to shed ancillary business functions down to core competencies, while outsourcing or even eschewing support services, the labor pool for support of automated processes is increasingly growing more homogenized, with a recognizeable gap [12] between the skilled and unskilled labor in the same skein of services, all of which works towards driving the cost, and need, for automation skills, automated labor, and automated solutions.

11.3.2 Operating Costs – Lease

Labor and benefits, as they pertain to the oil and gas industry, are being defined specifically as the cost of operation and maintenance of benefits for individuals employed directly within the industry, including individuals such as roustabouts, field workers, inspection engineers, and component production specialists, as well as support positions, like secondary or tertiary levels of support personnel, such as oil and gas company overhead. Based on an EIA study in 2016 [11], The price of oil, has a direct impact on the ability of oil industry companies to retain skilled labor, even when long term strategies rely on operating at a loss just to retain knowledgeable experts. Additionally, Federal regulations from agencies like Occupational Safety and Health Administration (OSHA) as well as the Environmental Protection Agency (EPA) have a direct impact on the cost viability and base ability of companies, especially during times of loss retention operations. EPA Studies [13], directed at cost options as they pertain to the benefits incurred solely based on U.S. methane production, show that the cost of coming into compliance with existent regulation alone will grow by upwards of 100% by 2025, not accounting for new and additionally proposed, as yet unseen regulations. Based on this, the operating cost of labor/benefits are both heavily affected by existing and proposed regulation, as well as the price of oil.

11.3.3 Operating Costs – Labor and Benefits

The growth in recent years of both software based and software controlled automation has been a boon for the oil and gas industry. The ability to remotely or autonomously regulate both equipment and facilities has had a dramatic impact in multiple sectors of the oil and gas industry [14]. Specifically, the replacement of onsite, low skilled labor with automation technology has allowed companies to defray costs typically set aside for liability and health benefits into the hiring of higher skilled labor and autonomous systems. The factors impacting labor are complex, as the replacement of lower skilled labor has been replaced by higher skilled labor with different skillsets and compensation expectations. Additionally, as noted in the labor analysis, the intentional retention of this class of skilled labor can incur costs when companies operate at a loss. Regulation of personnel, as well as the expense involved with lease operating costs, specifically as they pertain to day to day tasks, will both also play a heavy role on the amount of gains seen in the automation portion of the oil and gas sector.

11.3.4 International Tariffs on Exports

A tariff, by definition, is a tax imposed on the import or export of goods and in the case the term international tariff refers to the taxes imposed by other countries on petroleum products (oil and gas specifically) that are produced in the United States and exported to other countries for sale. The ability to sell oil and gas overseas goes to the bottom line profitability of Petroleum companies, as it is not always the case that an increase in a tariff rate will be passed along to the consumers of the product in the foreign country. Tariffs, however, work both ways and the United States measures its trade volume in areas of petroleum based on the term "net import" which is the total number of imports – the total number of exports.

"Current tariffs on oil imports range from 5.25% to 52.5% per barrel depending on the type of petroleum. 25 oil and petroleum products from certain countries are subject to duty-free treatment under several trade agreements and preferential trade programs enacted by Congress. The North American Free Trade Agreement (NAFTA), the Generalized System of Trade Preferences (GSP), and the African Growth and Opportunities Act (AGOA) account for most of the foregone revenue from waived tariffs. At 2010 import levels, these and other waiver programs accounted for about $180 million dollars in foregone revenue, down from $215 million in 2005 when import volumes were higher. In the past, an increase in the tariff on oil has been considered a means to provide an advantage to domestic oil producers and reduce imports [from other countries]" [15].

Therefore, when U.S. companies get a trade advantage through tariffs, this results in increased production in specific petroleum products as well as an increase in the ability to expand services and products produced in this industry, thus resulting in impacts to the unemployment rate. Nerurkar [15], goes on to say that "More than 60% of U.S. exports went to countries in the Western Hemisphere, particularly to countries such as Mexico and Canada from which the U.S. imports crude oil. Exports occur largely as a result of commercial decisions by oil market participants which

Figure 11.3: Crude oil price trends - 30 year history [15].

reflect current oil market conditions as well as past investment in refining". This leads to the conclusion that International Tariffs are not a major driving factor in the unemployment rates of the petroleum industry.

11.3.5 Price of Oil

As stated, earlier, based on an EIA study in 2016 [11], the price of oil, has a direct impact on the ability of oil industry companies to retain skilled labor and therefore is an impact to unemployment rates. The Price of Oil as seen in Figure 11.3 has fluctuated between less than $20 to as high as $160 dollars a barrel over the past thirty years.

According to one of the experts that participated on the TD team, when oil prices are low there is an employment ripple affect all the way up and down the support services and product line within the energy sector. Least affected in the recent history is the downstream refining. Most affected by price in the order of the employment ripple is:

- Drilling
- Drilling Support Services
- Engineering Services
- Field Development/Field Construction Ser-vices
- Production Equipment Providers
- Admin. Personnel
- Mgmt. Personnel
- Field Personnel.

Furthermore, this price of oil directly impacts the profitability of Petroleum Industry companies and is therefore directly linked to the central goal of the business aspects of these companies – namely, to make a profit for their shareholders. Following this logic, and considering the factors that impact profitability, all Operating

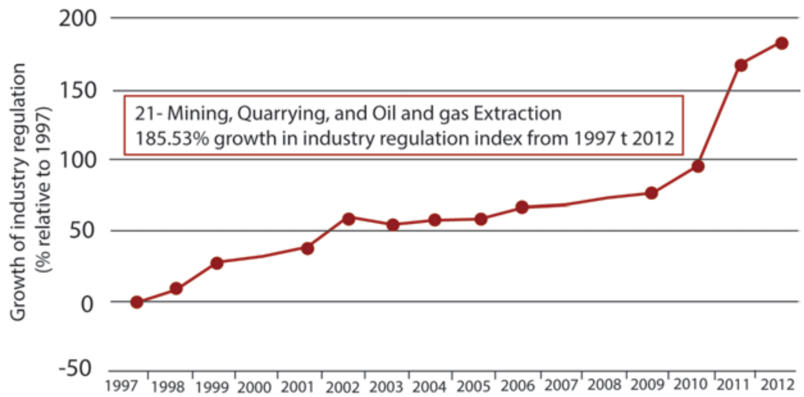

Figure 11.4: Historical regulation increase within mining, quarrying and oil and gas industry [16].

Costs, whether Lease costs or Labor and Benefits costs that impact profit margins must eventually be passed along through the price of oil in order to remain profitable. Additionally, International Tariffs and Regulations, both come with cost that is passed along to the company to respond to and be able to account for the overhead of paying for experts in these areas and sort through the legal paperwork and processes required to continue gaining permits and conducting operations. This cost impacts profitability and therefore the Price of Oil. It cannot be understated, however, the numerous complicating factors which impact the Price of Oil, thereby impact profitability and subsequently flow down to the unemployment rates within the Petroleum Industry.

11.3.6 Regulations

According to data collected by the Mercatus Center [16], three of the top ten regulatory bodies in the U.S., which have significantly increased their number of regulations in the last 15 years, directly influence and oversee aspects of the Petroleum Industry: Environmental Protection Agency (EPA), Operational Safety and Health Administration (OSHA) and Federal Energy Regulatory Commission (FERC). In fact, according to their data, of all the industries that have seen increases in regulations over the past fifteen years, the Mining, Quarrying and Oil & Gas Extraction regulations have increased 185.54% between 1997 and 2012 (see Figure 11.4).

New regulations, bring with them the opportunity for new employment opportunities at the higher end of the professional scale, such as lawyers and finance personnel. A higher degree of education or longer experience within the industry is required to fill these employment vacancies. This increased regulation can also delay new project development (at the front end engineering design phase and subsequent exploration and development phases) as the regulatory issues and process are worked through. The average number of days just to obtain a permit to drill on federal land from the Bureau of Land Management (BLM) was 307 [17] – and this is just one of many permits required throughout the process as the end to end process is regulated at each step: Leasing Land, Seismic Assessments, Site Preparation, Drilling, Well

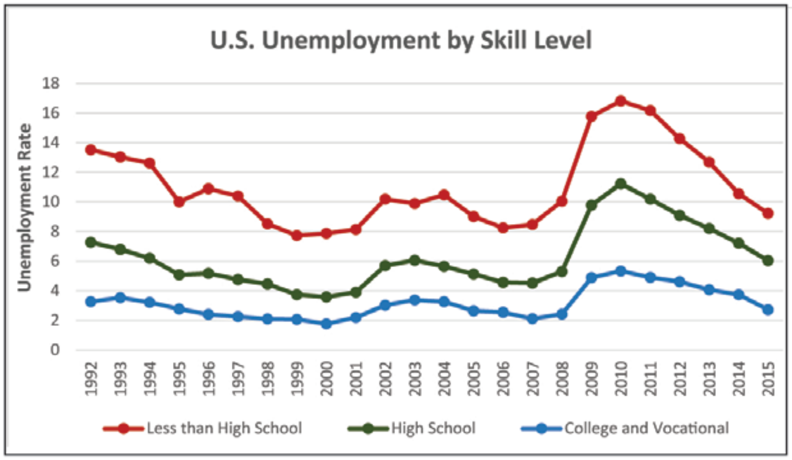

Figure 11.5: U.S. Unemployment by skill level [20].

Completion, Production and Restoration [18]. Each step is variable in timeframe, being impacted by regulatory paperwork and oversight, leading to difficulty in predicting employment needs, scheduling resources and work-loads in the industry and impacting hiring strategies as projects are delayed or not approved for continuation due to regulatory oversight. New regulations continue to increase and have a downstream impact on the unemployment rates within the Petroleum industry, driven in part by Social Issues such as Climate Change and New Technology development (e.g., Fracking).

11.3.7 Employee Education and Trade Skills

Education and trade skills describe the skill set of an individual. This skill set includes formal education, such as public high school and college as well as vocational schooling and skills acquired through on-the-job experience. Education and trade skills do not necessarily impact whether or not a petroleum job disappears, they do impact how quickly an individual can transition into another career or industry.

Unemployed workers whose skill set misaligns with the demands of industry are more likely to face long term unemployment [19]. Many of the manual laborers in the oil and gas industry, who face decreasing job security, fit into this category. Figure 11.5 plots the unemployment data [20] by education level.

According to the Bureau of Labor statistics, more than 50% of the workforce employed in oil and gas extraction, falls into the unskilled labor category. While many employed in the petroleum industry are highly skilled, those skills do not necessarily translate directly to careers in other industries [21]. For these employees, transitioning into a new career can require years of new training.

As discussed in the section on Automation Technology Increases, jobs are being lost due to automation of tasks that where once performed by manual labor. While many jobs are lost due to this (automation alone is expected to cut nearly 40% of the oil drilling jobs in Texas [22]), a smaller number of new jobs are created.

These new jobs, which require a different skill set from those that were lost, focus on information technology used to monitor and repair the automated technology. Employee education and trade skills can also impact automation and technology increases. Recent studies have noted a shortage of skilled labor, with some skilled labor jobs going unfilled [12]. After oil prices crashed in 2014, the industry reduced its workforce through lay-offs. Many of the laid off employees have since found jobs with other industries, such as the solar industry, which offers much better stability [23]. With oil prices on the rise and looking to ramp up, the industry is facing a shortage of skilled workers. When faced with a labor shortage, the petroleum industry may turn to automation, as other industries have [24] [25].

11.3.8 Social Issues

A social issue is an idea that influences a significant number of individuals within society, which may have both social and economic facets [26]. The petroleum industry has the potential to be impacted by several social issues:

- Environmental Pressure creating Market Demand for Clean Energy
- Human/Employee Rights, Environmental Protection, Transparency & Corruption issues. [27]

Considering first the social issue which is driving demand for renewable or clean energy. Studies have found that growth in the renewable energy sector has very little impact on the petroleum industry. This is because the two industries have different markets. Oil is mainly used for transport as vehicle fuel. In contrast, renewable energy sources are mainly used for power production. Oil makes up less than 1

The other social issues (human rights, environmental protection, and anticorruption) can have an impact on the petroleum industry, but mostly through the economic facets. These social issues can lead to laws and regulations, which could then in turn impact operating costs. An example of this can been seen with hydraulic fracturing. Hydraulic fracturing, or fracking, has been a practice used by the petroleum industry since the 1960s, however it has become a focal point of public concern recently. Fracking has risen to the status of a social issue as people became worried about environmental contamination and public health and safety concerns. In response to this social issue, some municipalities have passed laws and regulations banning the practice [30]. As hydraulic fracturing currently accounts for nearly 50% [31] of the oil produced in the U.S, it is clear, social issue driven regulation and laws do have the ability to impact the petroleum industry.

Social issues also have the ability to influence corporate behavior, stemming from the desire to avoid controversy. Oil drilling specifically can be the center of social controversy due to both environmental impacts and human safety. One response to these social pressures has been to turn to technology and automation. Technological advances have allowed industry to better predict where to drill. These analytical approaches allow for a better success rate when drilling for oil. This has multiple benefits, from reduced operating costs to fewer wells drilled, which leads to a smaller environmental footprint and fewer workers endangered [32].

		Price of Oil	Operating Costs-Lease	Operating Costs-Labor & Benefits	Regulations	Automation Technology Increases	International Tariffs on Exports	Social Issues	Employee Education and Trade Skills
		1	2	3	4	5	6	7	8
1	Price of Oil		A	A	A	O	A	O	O
2	Operating Costs-Lease			O	A	O	O	O	O
3	Operating Costs-Labor & Benefits				A	O	O	O	O
4	Regulations					A	O	A	O
5	Automation Technology Increases						O	V	X
6	International Tariffs on Exports							O	O
7	Social Issues								O
8	Employee Education and Trade Skills								

Figure 11.6: Structural Self-Interaction Matrix (SSIM).

11.4 Application of Interpretive Structural Modeling

The transdisciplinary approach to large complex problems, provides methods and tools to both understand and solve the issue. Interpretive Structural Modeling (ISM) is a methodology for dealing with complex problems, and it was developed by Dr. John N. Warfield in the early 1970s. ISM leverages graph theory, matrix theory, and mathematical logic, to assemble the influential factors in a meaningful way to develop a collective intelligence and solve complex problems. The following section will apply the ISM methodology to the issue of unemployment in the U.S. petroleum industry, and will break out the process and results for each step.

11.4.1 Modeling with Matrices

Using the influential factors and Kano Survey, both discussed in detail in Section 3, a Structural Self-Interaction Matrix (SSIM) can be created. The SSIM is an effective way to model the direction of the contextual relationship between the influential factors. Based on the influential factors discussed in Section 3, a SSIM has been created for this complex problem, as shown in Figure 11. 6.

The SSIM is just the first step in modeling the complex problem with matrices. In order to perform mathematical operations on the SSIM, it must be translated into a numerical format. Figure 11.7 shows this translation of the SSIM into the adjacency matrix.

The ISM process is based on the one-to-one correspondence between the binary

		Price of Oil	Operating Costs-Lease	Operating Costs-Labor & Benefits	Regulations	Automation Technology Increases	International Tariffs on Exports	Social Issues	Employee Education and Trade Skills
		1	2	3	4	5	6	7	8
1	Price of Oil	1	0	0	0	0	0	0	0
2	Operating Costs-Lease	1	1	0	0	0	0	0	0
3	Operating Costs-Labor & Benefits	1	0	1	0	0	0	0	0
4	Regulations	1	1	1	1	0	0	0	0
5	Automation Technology Increases	0	0	0	1	1	0	1	1
6	International Tariffs on Exports	1	0	0	0	0	1	0	0
7	Social Issues	0	0	0	1	0	0	1	0
8	Employee Education and Trade Skills	0	0	0	0	1	0	0	1

Figure 11.7: Adjacency matrix.

matrix and the graphical representation of a directed network. While a directional graph could be generated from this adjacency matrix, it may not correspond to the transitive contextual relation [33]. To accommodate the transitive contextual relationships, another method must be implemented. The reachability matrix and level partitioning are used to translate the adjacency matrix into the final directional graph. "In graph theory, reachability refers to the ability to get from one vertex to another within a graph." [34] The reachability matrix can be obtained by adding the identity matrix to the adjacency matrix, and then raising the resulting matrix to successive powers until no new entries are obtained [35]. Modelling the transitivity with the reachability matrix, results in the final reachability matrix, which is an interconnect matrix, which describes a single system whose reachability is wholly defined for the contextual relationship [33].

Using the adjacency matrix in Figure 11.7, and applying transitivity results in the final reachability matrix shown in Figure 8. When computing the final reachability matrix with transitivity, driving power and dependence factors are also calculated. These factors will be useful during the cross-impact analysis.

The utility of the reachability matrix is that it can be used to develop a hierarchical restructuring of the directional graph. To complete this, the final reachability matrix, with transitivity must be broken out into hieratically levels, which is accomplished through level partitioning.

		Price of Oil	Operating Costs-Lease	Operating Costs-Labor & Benefits	Regulations	Automation Technology Increases	International Tariffs on Exports	Social Issues	Employee Education and Trade Skills	
		1	2	3	4	5	6	7	8	
1	Price of Oil	1	0	0	0	0	0	0	0	1
2	Operating Costs-Lease	1	1	0	0	0	0	0	0	2
3	Operating Costs-Labor & Benefits	1	0	1	0	0	0	0	0	2
4	Regulations	1	1	1	1	0	0	0	0	4
5	Automation Technology Increases	1	1	1	1	1	0	1	1	7
6	International Tariffs on Exports	1	0	0	0	0	1	0	0	2
7	Social Issues	1	1	1	1	0	0	1	0	5
8	Employee Education and Trade Skills	0	0	0	1	1	0	1	1	4
	Dependence	7	4	4	4	2	1	3	2	$\sum = 27$

Figure 11.8: Reachability matrix with transitivity.

11.4.2 Charting the Results

Level partitioning is used to determine the hierarchical structure of the relationships between the influential factors. From the final reachability matrix, a reachability set and an antecedent set are derived for each factor, where the reachability set consists of the factor and the factors it impacts and the antecedent set consists of the factor and the factors that impact it. The intersection set for each factor, is defined as the set of factors that are present in both the reachability set and the antecedent set. From the structured description, partitioning is done in a cyclical way to order the indexing of the matrix. Following Warfield's partitioning method, the previously developed reachability matrix, Figure 11.8, hasto be structurally partitioned, and can be described as shown in Table 11.1.

With the level partitioning complete, the binary relational matrix can be converted into graphical form using the theory of directed graphs, or digraphs. Mapping the structural partitioning into a digraph is trivial, and the result is show in Figure 11.9. The digraph is a visual representation of the influential factors and their interdependence, with the hierarchical level increasing from top to bottom.

11.4.3 Cross-Impact Analysis

Cross-Impact Analysis (CIA) is a methodology for determining how relationships between factors, impact the resulting events. Completion the cross-impact analysis used the dependence and driving power factors, which were calculated for each of the influential factors in the final reachability matrix, previously discussed and shown in Figure 11.8. The cross-impact analysis was performed using the Impact Matrix

Table 11.1: Structural Partitioning

Variable	Reachability Set	Antecedent Set	Intersection Set	Level
1 Price of Oil	1	1,2,3,4,6,7	1	1
2 Operating Costs-Lease	1,2	2,4,5,7	2	2
3 Operating Costs-Labor & Benefits	1,3	3,4,5,7	3	2
4 Regulations	1,2,3,4	4,5,7,8	4	3
5 Automation Technology Increases	1,2,3,4,5,7,8	5,8	5,8	5
6 International Tariffs on Exports	1,6	6	6	2
7 Social Issues	1,2,3,4,7	5,7,8	7	4
8 Employee Education & Trade Skills	4,5,7,8	5,8	5,8	5

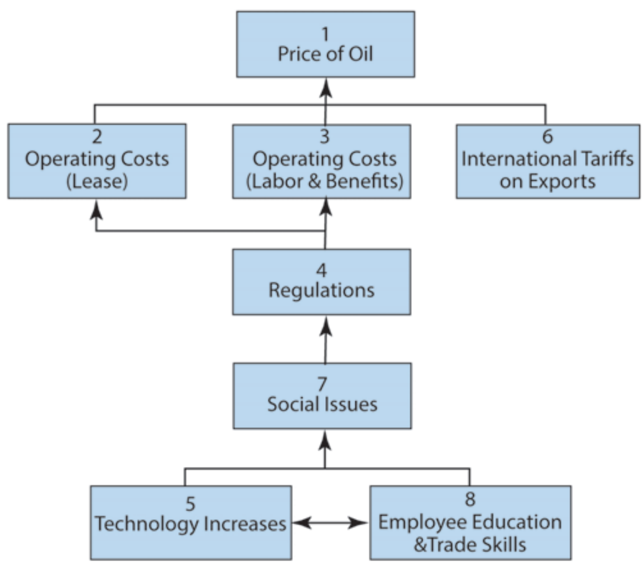

Figure 11.9: Digraph.

Cross-Reference Multiplication Applied to a Classification, or Matrice d'Impacts Croises-Multiplication Appliqúe an Classment (MICMAC), which identifies the in-

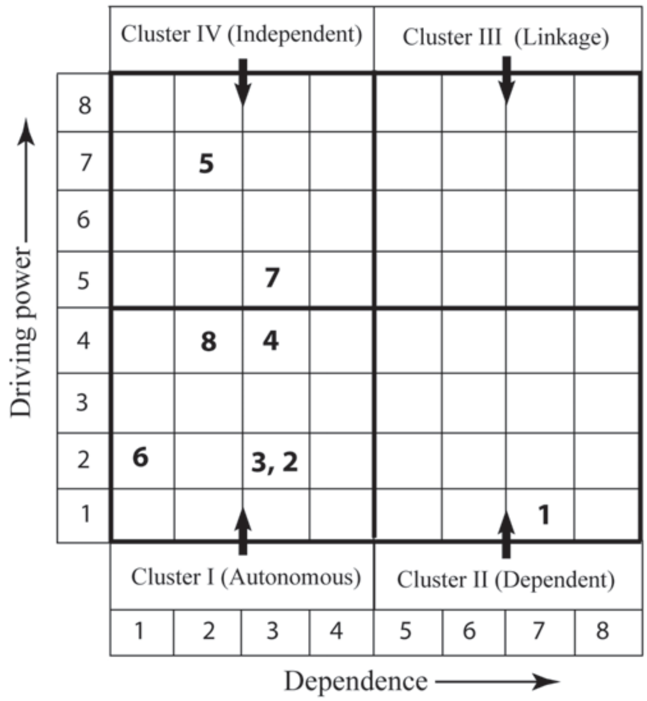

Figure 11.10: MICMAC Analysis.

fluential factors that drive the system in various categories; autonomous factors, dependent factors, linkage factors, and independent factors. The result of the MICMAC analysis for our problem, unemployment in the U.S. petroleum industry, is shown in Figure 11.10.

When assessing the results of the MICMAC analysis, the factors and their potential impacts are easily identifiable. Linkage factors which are considered unstable as they have a strong dependence and a strong drive are not a concern for this unemployment problem. The dependent factors, which have a weak drive and a strong dependence, may not be the best choice when determining which factors to impact to drive the desired results. For the problem, the only dependent factor is the price of oil. The independent factors are often called the key factors because they impact all of the other factors, and are not impacted by the other factors in return. From this it is clear, that Automation Technology Increases and Social Issues are the two most independent influential factors for this problem. The rest of the influential factors fall into the category of autonomous, meaning they have a weak drive power and a weak dependence.

11.5 Design Structure Matrix

Much like ISM, and other associated tools, the design structure matrix, or DSM, stands as an additional invaluable transdisciplinary tool for use in the deconstruction of complex situations and problems. Designed by Don Steward in the 1960's, the progenitor of the modern day design structure matrix (DSM) approach to the decomposition and evaluation of complex problems was that of using matrices for the production of solution sets comprised of multiple, differently modified matrices, for analysis to help better understand those problems. Based on this strong foundation, DSM, when used as a tool to evaluate complexity, evinces strong utility in the analysis of systems, and when used as a tool to understand the connections of multiple dependent factors, becomes a highly useful tool for project planning, as well as for systems and project design.

The choice of using DSM to help deconstruct and evaluate unemployment in the U.S. petroleum industry is based in part on these attributes, along with the applicability and validity of DSM as a tool within the transdisciplinary workspace. Worth noting, too, is DSM's flexibility in clustering and sequencing data, which is of great benefit when DSM is applied towards identifying factors in analysis to assist in the reduction of cost or schedule risk.

11.5.1 DSM – Base Tools and Potential Usage

Design Structure Matrix (DSM) analysis starts with the adjacency matrix, which was initially utilized for evaluation through ISM. Additionally, the factors chosen for inclusion are those identified in the Kano Survey conducted for the purposes of this paper, designed to identify and correlate the prevalent, impactful factors on unemployment in the U.S. petroleum industry. Techniques which can be used in the analysis of adjacency matrices, typically on larger, more fully interdependent factors, include techniques like the inclusion of multidomain matrices, in which two related sets of matrix data are combined into one. Partitioning is also a strategy typically used which evaluating adjacency matrices. Partitioning allows for more closely related factors within a larger pool of factors to be evaluated together, allowing for a better understanding of potential interdependencies. Additional Techniques available for DSM analysis include tearing, which allows for further analysis of related, looped factors. The objective with tearing, the use for which is outside the scope of the evaluation of the factors identified by the Kano Survey utilized for this paper, is to reorder coupled tasks within the identified blocks of an adjacency matrix, with the purpose of finding an initial ordering to start the iteration process of breaking down, and then reordering the factors involved [30]. Based on the fairly straight-forward nature of the factors found to be involved in the specific topic, the techniques in use with the evaluation of the Kano Survey results are limited to loop combination analysis.

11.5.2 DSM – Adjacency Matrix: Creation and Population, and Manipulation

The initial adjacency matrix, identified in Figure 11.11, was created by populating the matrix with the final factors identified in the associated Kano Survey as being most impactful. The tool used to create the diagrams included in this paper can be found at theatlas.org (which was free and publically available at the time of this paper's writing).

Next, the matrix was populated with dependent factors. Going by rows, each factor which acts upon another received an indicator of that action in the appropriate

		Price of Oil	Operating Costs- Lease	Operating Costs- Labor & Benefits	Regulations	Automation Technology Increases	International Tariffs on Exports	Social Issues	Employee Education and Trade Skills
		1	2	3	4	5	6	7	8
1	Price of Oil								
2	Operating Costs- Lease								
3	Operating Costs- Labor & Benefits								
4	Regulations								
5	Automation Technology Increases								
6	International Tariffs on Exports								
7	Social Issues								
8	Employee Education and Trade Skills								

Figure 11.11: Adjacency matrix, initial.

row / column location. The resultant adjacency matrix, identified in Figure 11.12, was the same as the one identified in the previous ISM evaluation. Note that the design matrix used for the evaluation of the unemployment factors does not have multiple domain mappings, and only deals with the unitary domain Found in the Kano Survey's factors (Figure 11.12).

Column six is empty, so column and row six get moved to the periphery (Figure 11.13). The adjusted adjacency matrix, indicates coupling between Automation Technology Increases and Employee Education and Trade Skills, (Figure 11.13), so these are collapsed into one factor for further evaluation (Figure 11.14). The collapsed chart indicates that the newly coupled multi factor column is empty, so it gets moved to the outside, which also moves the coupled row to the bottom (Figure 11.15). This action also completes the available interation with the adjacency matrix, so we uncouple the two factors coupled for evaluation, and identify our series and coupled factors (Figure 11.16).

From Figure 11.16, we can see with the two series, 'Lease Operating Costs' directly impacts 'Price of Oil', and that 'Regulations' directly impacts 'Operating Costs Associated with Labor and benefits', with additional coupling found between 'Employee education and trade skills' and 'Automation Technology Increases'.

11.5.3 DSM – Results

The final interesting factor was the looped dependency between automation technology increases and employee education and skilled labor availability. Automation

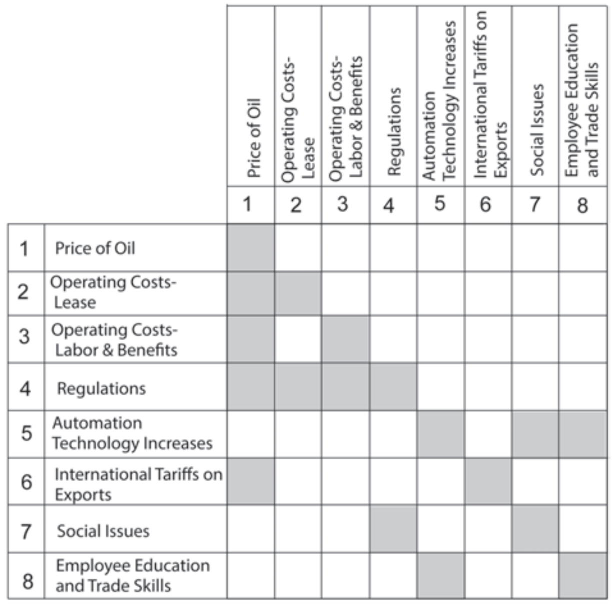

Figure 11.12: Adjacency matrix, populated.

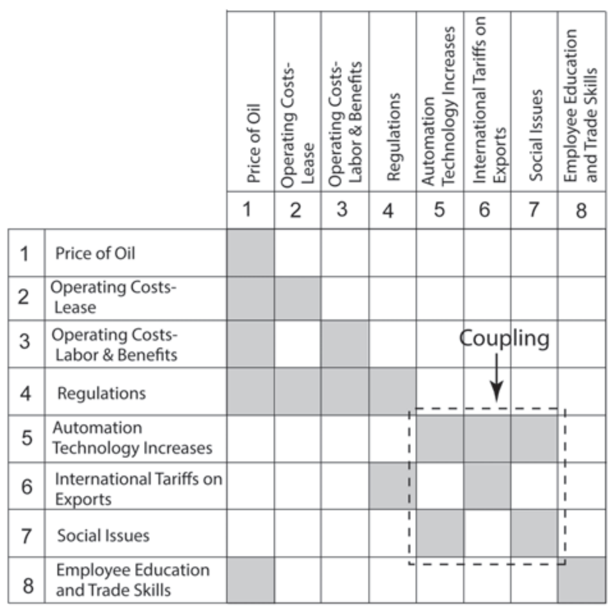

Figure 11.13: Adjacency matrix, adjusted.

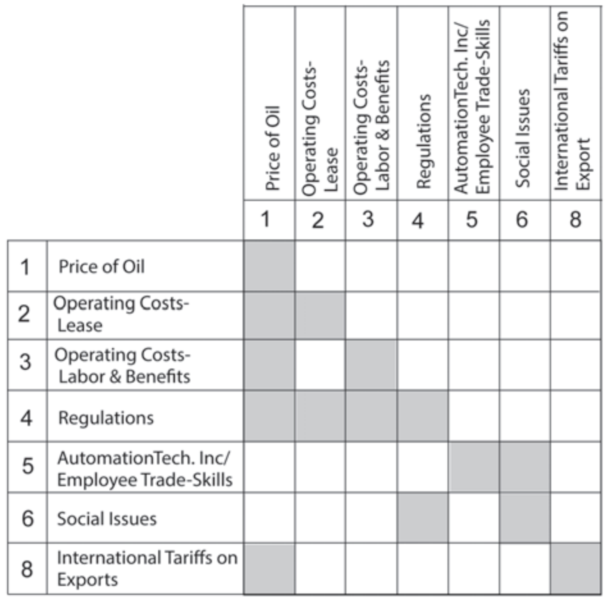

Figure 11.14: Adjacency matrix, collapsed.

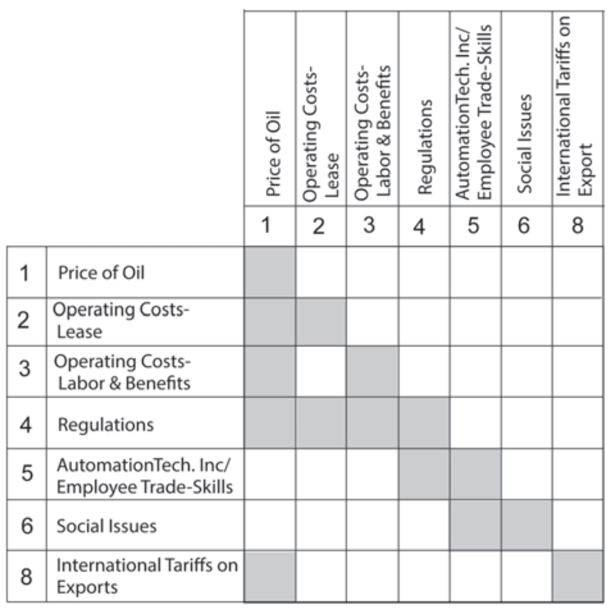

Figure 11.15: Adjacency matrix, collapsed, updated.

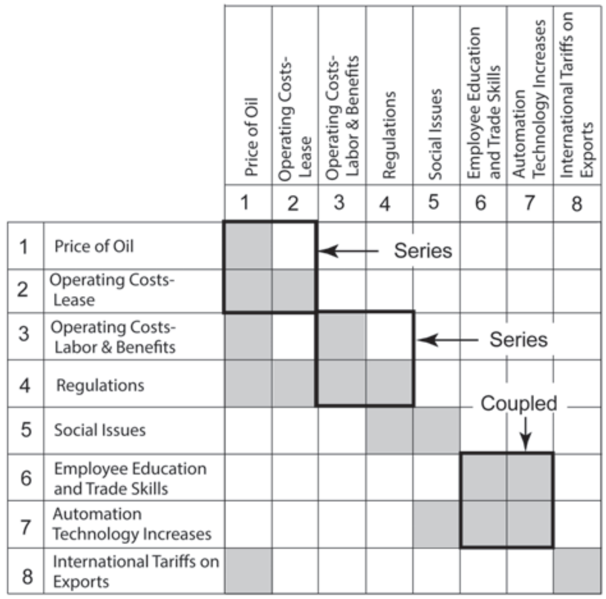

Figure 11.16: Adjacency matrix, final.

influences employee skill levels by seemingly perpetually requiring new and evolving skillsets. Employees, in turn, in order to maintain proficiency levels as well as reamain viable as candidates in an increasingly constricted labor to skill-set worker pool, must strive to keep updated their skillsets, in order to adapt to advances in fields like automation. Employee skill levels impact automation directly through the growing gap between unskilled and skilled labor. The growing educational requirements for technological based jobs, in fields like manufacturing, are being outpaced by the lack of adequately skilled labor (specifically defined as labor between unskilled and skilled) [12]. This gap, seen as a lack of viable labor for positions of moderate skill, drive requirements for automation, thus circuitiously driving an increase for highly skilled labor. In summation, while these two factors (automation and education) obviously greatly influence each other, their combined impact on factors like regulations had a large ripple throughout the rest of the significant factors identified as having a large impact on unemployment in the United States Petroleum Industry.

11.6 Conclusion

Having worked within the Transdisciplinary Research Process and through the application of ISM and DSM techniques, we conclude that investments in research and development of new technologies combined with efforts to increase the education level and skilled labor pool of employees within the United States will positively impact unemployment rates within the Petroleum Industry, as these factors drive the Price of Oil through an enumeration of factors discussed in the paper above. The Price of Oil directly goes to the bottom line profitability of Petroleum companies and therefore leads to employment/unemployment within the Petroleum Industry. It is this grass roots solution approach (e.g., education/skilled labor combined with the development of new technologies) that can directly address current and future unemployment issues in the Petroleum industry.

Future and more comprehensive research into these factors is required in order to provide additional levels of detail in the solution space. In particular, answering the question as to how secondary and post-secondary schools could isolate and expand applicable areas of education for future energy sector jobs as well as provide increased training in skilled labor, such as welding, would be valuable for the industry to understand. Additional research projects could lead to new educational tracks or standards as well as vocational school focus areas to help the Petroleum industry in its quest to draw down unemployment over the long run as well as provide stability its sector of the overall U.S. job market.

Overall, it is certain that investing in these areas: education and research & development of new technologies will lead to positive impacts for unemployment rates in the U.S. petroleum industry.

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The research team would like to acknowledge the efforts expended by Utku Gulbulak, in introducing and illustrating the Transdisciplinary Research Process to our team. Furthermore, our TD Team would like to acknowledge Mr. Robert Davis for his participation as a Subject Matter Expert during the early parts of the research. And finally, we would like to thank all of the participants of the Kano Survey that provided valuable input and insight that helped to shape the areas of our research: Ms. Britttney Davis, Mr. Brian Davis, Mr. Robert Davis, Mr. Ray West, Mr. Dewayne Kelley, Mr. Robert Evers, Mr. Beau Galloway, Mr. Tyson McMahon, and Mr. John Thomas among others.

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APPENDIX-A

Appendix of Abbreviations

AGOA – African Growth and Opportunities Act
BLM – Bureau of Land Management
CIA – Cross-Impact Analysis
DSM – Design Structure Matrix
EFC – Eagle Ford Capex
EIA – Energy Industry Administration
EPA – Environmental Protection Agency
FEED – Front End Engineering Design
FERC – Federal Energy Regulatory Commission
GDP – Gross Domestic Product
GSP – Generalized System of Trade Preferences
ISM – Interpretive Structural Modeling
LOE – Lease Operating Expenses
MICMAC – Impact Matrix Cross-Reference Multiplication Applied to a Classification
NAFTA – North American Free Trade Agreement
NGT – Nominal Group Technique
OPEC – Organization of the Petroleum Exporting Countries
OSHA – Occupational Safety and Health Administration
R&D – Research and Development
SPS – Societal Problem Solving
SSIM – Structural Self-Interaction Matrix
TD – Transdisciplinary
UAM – Updated Adjacency Matrix
U.S. – United States

Kano Survey

The Kano style survey below was used as part of the Transdisciplinary process in identifying the factors that were to be considered in the research. A large set of factors was initially conceived through brainstorming among the transdisciplinary team; however, the final selection of factors was driven by subject matter expert (SME) input from those who work and are decision makers in the Petroleum Industry.

Factor	M	O	A	I	R	Q	Category	Possible Categories
Cost of Labor and Benefits (Taxes, Insurance, Pension, etc)	9	1	1				M	M = Must Be
Social Issues (e.g., Climate Change Activism)	2	1	1	2	5		R	O = Optional
Individual Employee's Education/Tradecraft Skill Level	7	2		1	1		M	A = Attrractive
Regional Job Market Competition in the Energy Sector (Wind, Solar, Coal, etc)	3	2		5	1		I	I = Indifferent (No Preference)
US Regulations (EPA, OSHA, FERC, etc)	6	1	2	1	1		M	R = Reverse (Can be either way)
Lease Operating Expenses	6	1	1	2	1		M	Q = Questionable (Wrong Answer)
Price of Oil	9	1		1			M	
International Tariffs on US Oil & Gas exports	4	1	1	4	1		M	
Increase in the use of Automation Technology	2	4	1	3	1		O	
OPEC production and output amounts	4	1	2	3	1		M	
International Political Climate and Stability	2	1	1	5	2		I	
Individual Employee's Adaptability (e.g., willingness to relocate)	4	2		2	3		R	
US Import/Export Tariffs	3	1	1	5	1		I	

Figure A-1:
Kano survey results.

Customer Requirement		Negative Question (Dysfunctional)				
		1-I Like It That Way	2 - It Must be That Way	3 - Neutral	4 - I can Live with It that Way	5 - I dislike It that way
Positive Question (Functional)	1-I Like It That Way	Q	A	A	A	O
	2 - It Must be That Way	R	I	I	I	M
	3- Neutral	R	I	I	I	M
	4 - I can Live with It that Way	R	I	I	I	M
	5 - I dislike It that way	R	R	R	R	Q

M = Must Be
O = Optional
A = Attrractive
I = Indifferent (No Preference)
R = Reverse (Can be either way)
Q = Questionable (Wrong Answer)

Figure A-2:
Kano analysis mapping.

CHAPTER 12

From Instrumental Research in Art to its Sharing: Producing a Commons, Respecting the Singular

Samuel Bianchini, *École Nationale Supérieure des Arts Décoratifs - Paris (EnsAD) / PSL Research University, Paris*

Practice-based research in art and design, or "Research & Creation" ("Recherche & Creation" in French-speaking countries), is developing rapidly. Questioning the new relationships between artistic practices and academic research (as well as industrial) also leads to rethinking methods of cooperation and sharing between the arts and scientific disciplines. Based on an instrumental and even "organological" (after Gilbert Simondon and Bernard Stiegler) approach, research in art is examined here through the prism of "allographic" principles borrowed from Nelson Goodman, and then illustrated through several works. Subsequently, the fundamental as well as practical scope of such an instrumental and allographic model is demonstrated. Such a model in fact offers a solid base for the organization of a multidisciplinary team (which requires a redistribution of egos); for publishing and economic development strategies of various forms; as well as for a rethinking of the production of a commons whose methods of construction are based above all on the development of means that make the sharing of practices possible.

Keywords*:* Rechearch & creation, allographs, instrumental, distributed authority, art transfer.

12.1 Introduction

While practice-based research in art and design - or, in French-speaking countries, "Recherche & Création"[1] or more simply "recherche-création"[2] - is currently devel-

[1]Though originally seen from an instructional angle, "Recherche et Création" was introduced into French art schools through the Ateliers de recherches et création ("arcs" - research and creation workshops) instituted by Jacques Imbert [1]. It was as part of that dynamic that I edited a book on the subject [2]. We retain the term "Research & Creation" here, with an ampersand that helps identify the expression and at the same time reinforce the difference as well as the relationship between the two terms.

[2]This is the formulation preferred in Québec. Cf. for example: the conference La recherche-création : territoire d'innovation méthodologique, organized by Louise Poissant,

oping strongly, numerous questions remain: What is research in a school of art and design today? Why develop it and what purpose can it serve? What can a research approach, and what's more a doctorate, provide an artist? What are the pitfalls of such an approach? Why is creating not research, and vice-versa? How to posit a research question in line with academic criteria as well as artistic expectations? How to include that research in an established academic context? What is that context? Can it be changed? How to develop such research, in practice and in theory? What is practice-based research? How best to link practice and theory? What position to accord technology? What methods can serve as references, to be applied, adapted, or reinvented? Why work collectively rather than individually, and what do we have to gain and to lose? How do we organize ourselves, collectively and individually? How do we cooperate with other disciplines, in particular scientific ones (experimental sciences, human sciences, engineering sciences, etc.)? What can they offer us? What can we offer them? How to conceive of research in partnership with the private sector and even industry? How to enhance the value work produced in "Research & Creation"? What does publishing mean for a creator engaged in research?

12.2 Practice Based Research in Art: an Instrumental Research

Developing research in art and design indeed presents numerous questions, whether they be related to training in research and through research (in other words the supervision of student-researchers), to the development of research work (involving a team), or to the structuring of research (on an institutional level). As such research increases in our establishments - a reality that also questions those who are already engaged in the approach - publications addressing these questions are naturally more and more numerous. Indeed, it is not surprising to note that the first publications of reference on the subject were presented by the individuals directly involved in the development of such research - for example Bruce Archer [3] and Alain Findeli and Anne Coste [4] - in the institutions and countries concerned from the start, including the Royal College of Art in London [5] and various universities in Quebec [6]. The case of France is distinct: although design (which must be understood here as an "applied art") was long neglected with regard to research,[3] the fine arts have been

Jean Dubois, and Gisèle Trudel, Université du Québec à Montréal (UQAM), 19, 20 and 21 March 2014; Media Art Histories 2015, on the theme "RE-CREATE", organized by Hexagram, under the direction of Chris Salter (Concordia University) and Gisèle Trudel (Université du Québec à Montréal), Montréal, from 5 to 8 November 2015, addressing these issues with particular attention to their historical origins; and les États Généraux de la recherche-création, from 24 to 26 May 2016, organized by Université Laval, Québec, by Sophie Stévance (Canada Research Chair in Research-Creation in Music, Université Laval).

[3]Even though, in recent years, some French and France-based researchers have become more involved in questions relative to design, such as David Bihanic, Marie-Ange Brayer, Claire Brunet, Francesca Cozzolino, Sophie Fétro, Catherine Geel, Annie Gentes, Pierre-Damien Huyghe, Roxane Jubert, Annick Lantenois, Anthony Masure, Alexandra Midal, Nicolas Nova, Sophie Pène, Olivier Peyricot, Emanuele Quinz, Gilles Rouffineau and Stéphane Vial, most of them are not practitioners. We recall on this issue the recent conference on the subject: *La recherche en design, un enjeu pour Paris-Saclay,* organized by the École normale supérieure of Cachan, 15 and 16 October 2014.

present in universities, and therefore in research, since 1968.[4] Some methodological writings have therefore been produced by colleagues dedicated to better establishing fine arts research in the university.[5] While those writings insist on the need for a connection between practice and theory, they nevertheless remain reluctant to propose clear methodologies and objectives with regard to practice. One must certainly refrain from proposing principles too easily transformed into rules, which would be contradictory to artistic activity itself.[6] However, it is difficult to base oneself on those texts in building one's own practical path. The texts also suffer, quite often, from being based on the dearth of practice inherent to French universities, which struggle to support their art departments within their humanities and social science faculties, those not being materially or organizationally adapted, when the arts and design should be endowed with means similar to those provided for the engineering and experimental sciences. We must recall that in France it was above all music and sound research, and even, more broadly, audiovisual research, that opened the way for research in direct contact with creation, and that as early as 1943, under the impetus of Pierre Schaeffer (with the creation of the studio d'essai within the public broadcaster Radiodiffusion française, RDF), of the GRMC (Groupe de recherche de musique concrète, in 1951) which became the GRM (Groupe de recherche musicale, in 1958) and would later spread throughout France, and then of Pierre Boulez (in particular with the Ircam[7]).[8]

That we are immediately led to position research in art and design with respect to the engineering sciences, the natural sciences, or music, may not be accidental. All of those fields give pride of place to "instruments",[9] whether the term be understood in the musical sense or more broadly in its scientific context. As in those other disciplines - and for myself, confronted in my laboratory, EnsadLab, with the need to organize my team and manage student-researchers - this instrumental dimension

[4]In particular at Université Paris 8 - Vincennes - Saint-Denis, where Frank Popper created the first Fine Arts department in 1969, following, among other events, the cultural upheaval of 1968. Popper became head of the department in the fall of 1969. Jean-Louis Boissier participated alongside Frank Popper as early as 1969 in establishing the department. Reading the archives on a dedicated website [7] is profitable as is this book [8].

[5]It is surely Jean Lancri (at the time professor at Université Paris 1 Panthéon-Sorbonne) who was able to crystalize this academic approach with his text that is cited very frequently, including by researchers in Quebec [9]. Other academics have also contributed to better defining research in art in the context of French universities, including Jean Da Silva [10]. One approach often put forward by academic researchers, not unrelated to our proposals, consists of designating "poiesis" as a field of research in art, following the route opened, in particular, by René Passeron [11], pursuant to Paul Valéry.

[6]Perhaps we could still adopt this 18th-century Chinese approach: "The foundation of the One Brush Method resides in the absence of rules that engender the Rule; and the Rule thus obtained embraces the multiplicity of rules." [12].

[7]The terminology "research and creation" was probably first used at the IRCAM, which gave it an instrumental scope [13]. It is not unrelated to our own developments and those of Bernard Stiegler on organology, initiated when he was director of the institution.

[8]We should also mention the Acroe, Association pour la création et la recherche sur les outils d'expression, founded in 1976, which is fully part of an instrumental research that was, here again, first oriented toward music.

[9]Even if this approach is only rarely advanced in the experimental sciences, it is preponderant. See on this subject Bruno Latour's comments on "the presence of instruments", the place these means occupy in science - comments we take as our own, in the artistic field this time. For example, for the techniques, devices, apparatuses, and other means of inscription that can be "made into instruments" [14], pp. 42-45 and p. 49. of the downloadable version.

has emerged as a particularly structuring asset and a lever for the development of practice-based research in art, or, in other words, as a way of doing Research & Creation.

Indeed, it is in that way that the meaning of Research & Creation has already been supported and somewhat modeled [15], while retaining its essential openness and its societal significance, confirmed by Bernard Stiegler's organological approach [16].[10] In summary: the research dimension in Research & Creation projects is primarily devoted to means rather than ends. Research in art is therefore part of a process that can be described as "instrumental research", to the extent that we consider the instrumental dimension in its broadest sense: concerning not only objects made to be used and to allow for operations, but also what is related to processes associated with those objects and other devices, or even more conceptual ways of working. Research, being instrumental, would therefore be focused on means and techniques, and creation on ends, on works of various kinds. It is undoubtedly too radical to separate means and ends in this way, and even to use those terms; however, we allow ourselves the liberty in order to lay the simple and pragmatic foundations that we will go on to refine afterwards. It should also be noted that, though we are developing Research & Creation through this approach in our context,[11] we do not pretend to reduce the ensemble of the field to that framework. The more general definitions of research-creation, such as those proposed by the Social Sciences and Humanities Research Council of Canada,[12] as well as the Fonds de recherche du Québec – Société et culture,[13] suit us all the more because they include our position without difficulty. That position, however, must be understood as having a particular aim: we wish to develop "practice-based" Research & Creation *by* and *for* practice,[14] at a school of art and design that trains artists and designers above all, not theorists, educators, or mediators of art and design.

Aside from the fact that it is too simplistic, the "research/means - creation/ends" conception could mislead in two ways, implying both that time accorded to research and time accorded to creation are distinct, and that they are consecutive, the first leading to the second. While the distinction is worth preserving, the consecutive

[10] Here, p. 173. See also the colloquium we organized with Bernard Stiegler on the subject: *L'organogenèse. Pour un nouveau paradigme de recherche en art et en design,* international colloquium, 15 and 16 October 2015, École nationale supérieure des Arts Décoratifs, Paris. Program and videos available at: http://www.ensadlab.fr/fr/lorganogenese [last accessed 15 July 2017].

[11] Within the Reflective Interaction Research Group of EnsadLab, the laboratory of the École nationale supérieure des Arts Décoratifs - PSL Research University, Paris; including for our doctoral students in the SACRe program of PSL: "Sciences Arts Création Recherche".

[12] See the definition of research-creation: http://www.sshrc-crsh.gc.ca/funding-financement/programs-programmes/definitions-fra.aspx#a25 [last accessed 15 July 2017]

[13] See the definition of research-creation: http://www.frqsc.gouv.qc.ca/bourses-et-subventions/consulter-les-programmes-remplir-une-demande/bourse/appui-a-la-recherche-creation-concours-automne-2016-5aeb9wba1466537413107 [last accessed 15 July 2017]

[14] Though we make reference here to the categories proposed by Christopher Frayling - Research *into* or *through* or for art and design (*in Op. Cit.*), we nonetheless depart from it by considering the necessary link between *by* and *for* art, which is to say aiming for research *by* art that obtains results *for* art. That objective ("for art") is not, then, an end in itself, but must catalyze research, obliterate it the better to revive it, introducing an iterative dynamic between means and ends and thus avoiding lapsing into the principle of art for art's sake.

relationship absolutely is not. On the contrary, the relationship between means and ends is not fixed. Continual back-and-forth interactions are the proof of a subtle relationship between means and ends, in an experimental and iterative dynamic; far from being marginal in Research & Creation, that way of doing things is in fact a very common process. While the distinction between research and creation needs to be refined[15]- in particular in the relationships between art and technology - it is nonetheless valuable and makes it possible to respond to many organizational and methodological questions that have institutional consequences.

12.3 Research & Creation through the Notion of Allographic Arts

To pursue that refining, it is useful to look to Nelson Goodman's theses about the so-called "allographic" arts, because our conception of Research & Creation argues in favor of a two-stage art, or rather one with two types of "manifestations", or two states. Let us return briefly to that concept proposed by Nelson Goodman [18] [19]. The "allographic" notion was initially proposed in a context that does not, a priori, have much in common with ours, but it is useful for us and we would like to extend it in a direction that will enable us to develop it to the benefit of our methodology. Allographic art[16] is defined by an ideal form of notation distinct from the final form the work takes. Thus, the execution of a musical score makes the art work, and as long as the score is respected, there is a work, which is unfakable because replicable at will. While there is a work at the moment of its instantiation, for that to take place, it must be prepared, conditioned, formalized, and specified through notation. That notation, or spelling, is itself dependent on an established language that makes possible an "orthographic"[17] relationship to the work, which is to say one that validates the respectful execution of that notation during its instantiation.[18] There is a stage for the ideal formalization (notation) and a stage for the instantiation. While those stages often occur in that order, they can also be ordered inversely, as

[15]It will be understood, then, that if the distinction between means and ends is necessary for establishing a clear and pragmatic methodology, their iterative and subtle relationship, and the chosen angle of approach, such as that of research (for which the means are also an end), can enable a reshuffling of the cards, as Bruno Latour does [17].

[16]It should be noted that the synthesis we are attempting is not that simple, since Nelson Goodman himself progressively developed that dual autographic/allographic regime, first in his work *Languages of Art: An Approach to a Theory of Symbols* [18], pp. 112-123, and then coming back to it and adding precisions and nuances in a subsequent publication, *Of Mind and Other Matters* [19], pp. 139-145. It is in that second book that he states that the two stages that might characterize an allographic art are perhaps not necessary in certain cases and that one can qualify the two stages as "execution" and "implementation". Implementation would, briefly, be a matter of setting the work in operation in public. I myself proposed considering a third "actographic" regime, when execution and implementation are done *with* the public, or more broadly the context, which updates, instantiates the work so that it works, so that it occurs [20].

[17]The word "orthographic" is the one used by the French translator of Nelson Goodman's *Languages of Art* [18], Jacques Morizot, with the first reference on page 152 of the French version. In lieu of Goodman's original "spelling" and "correct spelling", we take the liberty of preserving the translated "orthographic" in English, as it seems particularly charged with meaning when used to describe the integrity of the execution of an allographic work.

[18]Nelson Goodman, *Languages of Art* [18], Op. Cit., p.121.

when one produces notation from a musical improvisation, or, more broadly, from an experiment.

Though our synthesis is inevitably too brief, we nonetheless retain the principle of an art founded on that dual form, and, beyond a state of only notation, we suppose what is more broadly a moment of instrumental research and preparation. That stage of work can lead to specifications.[19]

But, for research in art, the instrumental conditions are not necessarily respectful of established protocols: they are themselves the object of redefinition or research for one or several original instantiations. One does not play with the rules of an established instrumentarium, but one can reinvent it and its mode of instantiation, at least in part.

Though we take some liberties with the allographic principle itself, based on a conventional notation allowing for an orthographic interpretation, let us nonetheless return to several constituent points of that regime likely to enrich our approach. In addition to the two-step staging (regardless of the order) that we appropriate, albeit with the "instrument/work" pair, two other aspects specific to the allographic regime converge with our approach: the first stage can give rise to specifications, and, for that reason, it allows for collective work.

Indeed, Nelson Goodman returned several times to two salient points of allographic works:

> "Where the works are transitory, as in singing and reciting, or require many persons for their production, as in architecture and symphonic music, a notation may be devised in order to transcend the limitations of time and the individual."[20]

If, for Nelson Goodman, the "notation/instantiation" relationship implies an ephemeral execution, it also allows for collaboration in the execution, thanks to a system of notation shared according to established conventions.

If, more broadly, it is an instrumental regime that we retain in the first stage, it can also be shared according to clarified means of description and specification, and therefore allow for cooperative or collaborative work in the place of instrumental research. Such collective work, propelled by a shared interest and by shared protocols and specifications, can be multidisciplinary, for example permitting a convergence between an instrumental approach typical of the engineering or experimental sciences (physics, chemistry, biology...) and another from the domain of art. Not only is the collective character of research thus made possible, including for the arts, but it is most often necessary, because this instrumental research is complex, rarely conceivable at the level of the individual or of a single discipline.

Finally, and this is a return to the source of the allographic, this regime is built on a principle: "the unfakable".[21] Indeed, since the work is an instantiation, any instantiation consistent with the notation is an execution of the work, and any duplication of the notation that is spelled correctly is of the same value. Thus, with notation and work duplicable at will, faking has no meaning. Formalization as notation indeed allows for execution. However, is this not also the basis of the patent,

[19] Nelson Goodman himself integrated that possibility of notation: "Any building that conforms to the plans and specifications...", *Idem*, p. 120.

[20] *Idem* p. 121. Then the same idea is repeated on the next page of the same book, and again in *Of Mind and Other Matters* [19], p. 140.

[21] This is even the title of a sub-section of the work *Languages of Art* [18] in which Nelson Goodman developed the notions of autographic and allographic, *Idem.* p. 112.

which is kept secret, and of the public license, which must remain public? Indeed, the basic principle of a patent or public license consists of a precise description of a process (a technique, an apparatus, an instrument, etc.) allowing for its execution by any person skilled in the art. It is on the basis of a specification equivalent to notation that the object of the patent or public license can be produced. In other words, what makes forgery impossible in the case of allographic art is, for the same reason, what must be protected in the case of a patent or public license. And it is for that reason that we can go beyond the notion of notation by extending it to all forms of specification. Any instrumental approach, including artistic, if it is original and specified as it should be, can benefit from legal protection and a transfer for possible use, artistic or non-artistic. Any economic advantage then relates to the instrumentarium, the object of the research stage that is independent of the creation that uses the instruments. And those latter, stimulated by artistic creation, initially for that creation, can give rise to economic advantages and therefore uses other than those of artistic creation, leading to appropriate legal and economic forms. The various actors can then distribute the potential gains in relation to their various disciplines, their respective contributions, and the field of application (execution) of the instrumentarium in question. Thus artists could retain rights for artistic applications, scientists could preserve them for scientific applications, and both could share the potential benefits from industrial transfers, negotiating on a case by case basis. Ultimately, such economic advantages relate to the instrumental stage, the research stage that is collective, most often multidisciplinary, and that needs to be formalized in order to be shared, both during the work of development and during the use that is open to others. Once formalized and modeled, that stage increases universal practical knowledge and truly responds to the fundamental issues of research.

12.4 Examples of Research & Creation Projects

Since this is, first and foremost, a question of practice-based research, it is essential to base our approach on examples. Several have already been presented in the previously-mentioned preliminary publication [15] as the *Behavioral Objects* project and its modular robotics kit (*MisB Kit*)[22] or the software framework *Mobilizing* developped and used for many projects as the recent Research & Creation Workshop *Where am* I, under the direction of Dominique Cunin (see Figures 12.1 (a) and (b)). However, we can briefly present another Research & Creation project that corresponds to this approach.

In 2010, I was contacted by the French Alternative Energies and Atomic Energy Commission (Commissariat à l'énergie atomique et aux énergies alternatives - CEA) in Saclay, near Paris, to work with them on a project that would implement a result of their chemistry research on the treatment of surfaces. We developed a process to prepare glass surfaces - in a way invisible to the naked eye - so that water falling on a surface would form a pattern, attracted by some zones and repelled by others. That process was driven very early on by an artistic project that was completed in 2016: *Mourners* (see Figure 12.2 (a) and (b))

The *Mourners* project employs the well-known phenomenon of drops of water finding their way down a window, but it controls the course of the drops as well

[22] Cf. : http://misbkit.ensadlab.fr [accessed July 15, 2017]. This "Behavioral Objects" project and its modular robotics kit *MisB Kit* is also presented in another publication [21].

(a) (b)

Figure 12.1: (a) and (b): Where am I?, 2017, Research & Creation Workshop under the direction of Dominique Cunin (EnsadLab / Reflective Interaction). Experimentation of video-mapping and collective interaction with smartphones, La Gaîté lyrique, Paris, December 2017, with the support of the Chaire Arts et Sciences of the École polytechnique, the École nationale supérieure des Arts Décoratifs, and the Daniel and Nina Carasso Foundation. This workshop contributed to the development of Mobilizing.js (http://www.mobilizing-js.net), a programming environment for mobile screens, conceived by EnsadLab and aimed at artists and designers. Photos: Samuel Bianchini.

as their production. Plates of glass of human size, positioned like stelae, let drops of water - emerging from a sort of water flute created for the installation - flow down their surface. The drops do not seem to move randomly toward the ground, but take meandering routes, following invisible paths, accelerating, decelerating to form sketches of human figures whose expressions are, in fact, conditioned by that process and materiality. Subtly lit, the glass plates rest on mirrors that encourage the play of reflections and gazes: they reveal faces and bodies, those of mourners on their surface as well as others seen through them or reflected on them, those of the viewers. Such subjects have, since antiquity, associated deep feeling and pretense, affect and representation. Pursuing that tension, here the sensitive meets the most advanced technology to communicate feeling, through absence or through transparency.

Based on an innovative dispositif and process, the artistic project also stimulated developments that required numerous experiments and iterations between means and ends. And those ends may be plural, because it is a practical potential of creation that is therefore produced and that can stimulate new projects, themselves sources of new developments, for example for the work *At Present*[23] (see Figure 12.1 (a) and

[23] *At Present*, which required a rethinking of the process used in *Mourners* for typography, can briefly be described as follows: drops of water fall on a glass stele; they do not seem to be moving randomly, they wander, follow invisible bends and form letters and parts of letters; they provide glimpses of words, a sentence, the epitaph of a thinker, Félix Guattari.

(a) (b)

Figure 12.2: (a) and (b): *Mourners*, installation, 2010-2016. Samuel Bianchini with the collaboration of Pascal Viel (CEA). Collaboration on the technical process: Daniel Desforge (CEA) | Instrumental glassware: Bruno Coltrinari (CEA) | Collaboration on the surface chemistry: Geoffrey Barral (CEA) | Scientific mediation: François Bugeon (CEA) | Artistic mediation: Mari Linnman (3CA) Production assistance: Élodie Tincq | Assistance for creating the figures: Olivain Porry. Acknowledgements: Rémy Albert, Christophe Aubry, Cécile Baudin, Marc Billon, Patrick Champion, Michel Delarasse, Bruno Delomez, Michel De Sousa, Maud Gallois, Pascal Godon, Robin Guibal, Nassim Hanifi, Olivier Kuster, Gilles Le Chevallier, Guillaume Le Chevallier, François Legrand, Clément Moussay, Arnaud Poirel, Alain Porcher, Mathieu Porchet, Jean-Marc Reymond, Jean-Luc Sida, Marie Vandermersch, Clarisse Viel. This project was created with support from the Saclay research center of the French Alternative Energies and Atomic Energy Commission (CEA Commissariat à l'énergie atomique et aux énergies alternatives), Diagonale (Université Paris-Saclay), and the Department of the Essonne. La Crypte, Orsay, November 2016. Photos : Samuel Bianchini.

12.3), created in 2017 in the wake of Mourners. A virtuous loop had been established. Based on multidisciplinary collaboration, it can also be shared, particularly with regard to the process that was created.

Other examples clearly demonstrate the potential of this approach. We can quickly present a few historic ones, focusing for the most part their instrumental innovation. Emmanuel Carlier, for example, who, for his work *Temps Mort* (1995) presented at the Lyon Biennale [22] that same year, began inventing, in 1993 - and in a direct line descending from Étienne-Jules Marey and Eadweard Muybridge - a process based on an apparatus for taking simultaneous photographs, in 360°, with a large number of cameras around the same scene (for example 36 cameras to have one every 10°; 70 cameras in the case of *Temps Mort*). The series of photographs

Figure 12.3: *At Present (Félix Guattari)*, installation, 2017. Samuel Bianchini with the collaboration of Pascal Viel (CEA). Collaboration on the technical process: Daniel Desforge (CEA) | Instrumental glasswork: Bruno Coltrinari (CEA) | Collaboration on the surface chemistry: Geoffrey Barral (CEA) | Scientific mediation: François Bugeon (CEA) | Production assistance: Élodie Tincq This project was created with support from the Fundamental Research Department of the French Alternative Energies and Atomic Energy Commission (CEA Commissariat à l'énergie atomique et aux énergies alternatives), the CEA-Saclay research center, and Le Diagonale Paris-Saclay. *Curiositas* Exhibition, Château de Button, Gif-sur-Yvette, May 2017. Photo: Samuel Bianchini.

produced in this way made it possible to turn around an object frozen in movement. Used subsequently in videos and more minor films, Carlier's process was made hugely popular by the Wachowskis, who called it bullet time, in *The Matrix.* David Rokeby is also engaged in an instrumental research approach, carrying out, since 1982, computer

innovations for his *Very Nervous System*, collected in software, softVNS, that continues to be distributed for use by other creators, as Jean Gagnon describes [23]. In the same vein, one could retrospectively consider certain works or approaches by artists as pertaining to instrumental research, such as Dziga Vertov and his moving picture systems, and Sergei Eisenstein and his editing experiments and theories. Let us also recall Marcel Duchamp and his optical machine (*Rotorelief*) that even participated in the 1935 Concours Lépine; Pierre Schaeffer and Jacques Poullin (and their *Phonogènes* series, from 1951); Fujiko Nakaya for her Fog Sculpture process on which she began work in 1970 (patented in 1989[24]); the Vasulkas and their image synthesizers; and other devices like those of the Machine Vision series,[25] begun in 1975; or even certain literary techniques such as the cut-up employed by William S. Burroughs, after Brion Gysin; as well as works by Dan Graham, Piotr Kowalski, and, more recently, by Jim Campbell, Olafur Eliasson, Wim Delvoye, Rafael Lozano-Hemmer, Hubert Duprat, etc.

12.5 Singularity and Sharing

Creation is not the equivalent of research, but many artists nonetheless develop their own processes, their own techniques, their own instruments. While that step is necessary, it is not enough to qualify such an approach as research, strictly speaking. For that, artists must also translate the research to make it shareable, be it practically in instrumental form (instrument, apparatus, software, notation, protocol, etc.), and/or theoretically in the form of knowledge (theory [publication], patent, license [including public licenses], or any other specification or prescription enabling its use by others). On the other hand, while that effort at transmission must be underlined, it is in no way a guarantee of artistic quality; certain artists, such as Jeffrey Shaw, with his EVE project, may be major instrumental creators - of apparatuses, for example - without actually implementing all of their developments. Many artists may, however, consider that their instrumental research should not be shared, in order to preserve the singularity of their work in which it is used. They may also argue that the work of modeling and translation does not have to be their responsibility. One might object that it is a shame to see artists like Emmanuel Carlier being robbed of their research - especially by people from non-artistic fields, the cultural industries and advertising first among them - without the benefit of a return of any kind, while we know how hard it is to live from one's artistic production. When that return is lucrative, it would offer an alternative to the art market alone. Another kind of recognition is also possible, based on open source methods: by associating our names with these instrumental developments, when others take them up and use or modify them, they also ensure the dissemination of our names, and our egos, the incarnation of the distributed authority so precociously anticipated by Roy Ascott.[26]

Though these questions of the redistribution of authority (and of ego) may seem peripheral to the subject at hand, that is not in fact so. They inevitably become central, or rather permanent and diffuse, laden with unspoken expectations, each individual trying to subtly recoup their investment as quickly as possible, exploiting results while participating as little as possible in their development. As the head

[24] System for making a cloud sculpture from water-fog, Patent #1502386, Cf. Fujiko Nakaya [24].

[25] Cf. Catalog of the *3ème Biennale d'art contemporain de Lyon: installation, cinéma, vidéo, informatique, Op. Cit.,* p. 132-133. Or the website of the Fondation Daniel Langlois http://www.fondation-langlois.org/html/f/page.php?NumPage=423 [accessed July 15, 2017]. According to Don Foresta, the Vasulkas "are artists' artists". That mise en abyme clearly reveals the capacity to be useful to other artists, and to the arts in general, through an instrumental and therefore transferable approach.

[26] Roy Ascott introduced the "distributed author" notion during the creation of his project *The Pleating of the Text: A Planetary Fairy Tale* in 1983 during the*Electra* exhibition at the Musée d'art moderne de la Ville de Paris. See, for example, the case of an artist who creates artifacts, such as Golan Levin.

of a research team in a school of art and design, I am confronted on a daily basis with student-researchers and creator-researchers who, for the most part art-school trained, tend to focus on their own individual, short-term advancement, thinking that recognition results from a break with their institution: crediting a team and an institution in which part of the research work was accomplished would be tantamount to relinquishing part or their authority, and presenting themselves as subservient or even student-like in the eyes of an art world that needs names, single unaffiliated signatures, individual geniuses. And so ensuring respect for credit where credit is due[27] is a still a daily struggle that requires constant, ceaseless explaining about the validity of this approach in our context while highlighting a reality, a wager to be made: that by investing in research which is necessarily prospective and often complex and that calls for a collective, multidisciplinary approach, one can later benefit from the results and use them in a singular and original way. Fair's fair.

How can one use this research in a singular and original way? Through creation. On the one hand because this research is usable, because instrumental, and, on the other hand, because it emerges from a need to create: it derives, as we have already seen, either from a creative project or from a desire to experiment. Creation is both an engine for and a result of research. There is, moreover, we repeat, no consecutive relationship between research and creation, but rather recursiveness, the one energizing the other, with, at the center, experimentation carried out according to requirements that may be scientific or technical, but are above all artistic. Because it is according to artistic criteria that the results will be judged in our community, which is at the convergence of practice-based research in art and professional artistic circles. Of course, if that research can also meet the scientific criteria established by that other community, then the multidisciplinary approach will emerge with increased stature. For there is, for scientists, another wager to be made: that of trusting artists. Artists' concerns, often laden with intense projection as to how the work will be received by an audience, can motivate an entire team, including the scientists. On the other hand, the artists must understand that they cannot expect everything from the sciences: there is no magical engineering that will satisfy their technical fantasies. And we must get beyond the too-frequent confusion among artists between science and engineering. Engineering is an extremely precious third-party that must be integrated into a subtle triangulation with the arts and the sciences[28] at a time when technology has become central. A third party to everything, technology mediates and conditions every sphere of our societies. The instrumental situation that we describe contributes to investment there, not to conform to it, but to invent, rearrange, and orient those technologies and to propose alternative, sensitive, and emancipatory implementation methods.

While many of the needs and developments specific to a work participate in enriching the instrument, certain adaptations of the instrumentarium cannot become part of generic, instrumental, shareable, and modelable developments. A subtle arbitration is often necessary then to respect the appropriation of the instrument contributing a specificity to the work, guarantor of its originality. This is where one

[27]Such credits are essential: they give an account of the creators, the context, even the history of the production, thereby emerging as a sort of "pedigree" of the work. Their fair hierarchy does not challenge the authority of the artists; on the contrary, it redistributes it.

[28]As such, it is not surprising that what enabled the development of EAT is without a doubt the position occupied by Billy Klüver, engineer, founder, and main person in charge of EAT.

of the problems in instrumental research arises: once the original means are shared, will they not they confer a "family resemblance", a similar technique, to all of the creative projects that employ them? For that reason, it seems important to be able to appropriate research in a singular fashion while being vigilant (research directors in particular) as regards generic developments in the service of a community (or even of all) and singular developments for an equally singular work.[29] Though it is here a question of singularity, one must nonetheless take into account the fact that singularity is not necessarily the product of a single individual, but can also be the product of a collective. Alongside the pursuit of singularity, it is also essential to defend new artistic practices, some of which fall under the concept of distributed authority, accepting that the creations are part of shared research by defending and citing that research.

Another difficulty still needs to be discussed: how to do research for the non-allographic arts, the autographic, one-stage arts? Through the prism of our approach, what is, for example, research in painting? Despite the fact that the practice of such arts usually occurs in one stage, it seems possible to loosen and break those practices into stages in order to investigate them better, focusing on a preparatory, experimental stage requiring the development of news ways of working, new means. And so a research stage prior to creation, to implementation, can be imagined, as if we were "allographing" a technique in order to bring it into research. In painting, it could, for example, relate to pigments, media, principles of composition, "stratification" of layers, touch, transparency, etc. Of course many painters integrate these concerns, more or less intuitively or rationally. However, do they seek to systematize or model those efforts - to any extent - in order to share them through an instrumental approach and/or a theorization of their practice? These artists, to make their exploration public, could exhibit their path through a series of works, which are so many steps or paths or declensions.[30] Such works embody original exploration that can be experienced aesthetically when they are contemplated, but they are not intended to share their means in other ways, in theory or in practice. Or it could be via second parties: theorists, critics, journalists, etc. who, to a certain extent, can accompany the works and offer them another form of visibility or understanding, and, sometimes, an "instrumental" scope within their community of peers - artists - who can base themselves on that work to develop their own.

12.6 Making the Work Public: Exhibition, "Publicizing" and "Art Transfer"

Research, as already constituted in every discipline, necessarily includes a sharing dimension: it has the vocation of increasing universal knowledge, even if that means questioning past knowledge. For research in art, that knowledge is practical and must be able to be embodied, conveyed, and published in ways that cannot be held only to the standards of academic publications. Publication must be understood in its most basic sense: to make public. The arts are not at all lacking for means of making

[29] See for example the creative projects carried out alongside the development of our modular robotics kit, the MisB KIT, at EnsadLab, *Op. Cit.*

[30] One could, for example, think of Robert Ryman or Gerhard Richter, but those examples must be relativized because those artists also published texts about their practice, which is probably revealing with regard to the "research" dimension of their approach [25] [26].

public, starting with exhibitions. Rethinking the multiple forms of publication and publicizing is essential and strategic when considering the development of research in art and its social, even political impacts. And, in return, that investment can also enable a reevaluation of how to make art public, beyond the usual methods.[31] While creations implementing instrumental research and developments are, in fact, good vehicles for publicizing - if only because they can be exposed - many kinds of publicizing, of sharing, can take place on the basis of instrumental research itself. Thus, transfer, in the industrial as well as the more broadly societal sense, can mainly be achieved starting from that stage of research and its instrumental production.

This two-stage, or rather two-state organization - so as, once again, not to vectorize the whole - can and must also be taken into account with regard to the resulting legal aspects, in particular in the drafting of contracts that the laboratory and the creator-researchers can sign with partners, both public and private. The same is true for contracts between researchers and their own institutions. Thus we distinguish the instruments, devices, technical chains, etc. invented for the project from their applications, in particular artistic. Rights, exclusive or not, can be ceded for applications, sometimes with restrictions on one or more fields of application. For example, an art research laboratory may retain the exclusive right of application in the artistic field, but relinquish its rights to industrial applications, detailing the terms, as is usual. In any case, the art research laboratory, like all researchers in these disciplines, must not relinquish their exclusive rights to the instruments that they invent and that materialize their research, otherwise they will lose all of the benefits, whether those be the knowledge and expertise acquired and implemented or the possibilities for future development and creation.

Being practice-based, research in art focused on an instrumental dimension is also a source of practice, it comes from practice, and it stimulates practice: indeed, it is constituted by and for practice. Though this research is developed by a community for that community, as art - or as part of artistic projects - it is inherently concerned, unlike the sciences, with how it will make itself public. It does so, naturally, by being exhibited. But at a time when there is more and more talk about fablabs, open source and now open innovation, makers, etc., the aesthetic experience is no longer necessarily that of “finished products", but can also emerge from practical experience. Though not demonstrations, the works emanating from such research processes particularly encourage an examination of the original progression of their production, the practices of which they are the fruit. Some of them can even become “practicable” [27], offering the test of their conditions as an aesthetic and practical experience. Practice is not the custom, it does not conform to the rules in force, but invents itself in action. Far from the “producer/consumer”, “transmitter/receiver” dichotomies, practice represents an intermediary space, a porous space where the roles can be open, permeable, even redistributed, in particular for art and its research, stronger thanks to its public vocation.

Sharing and stimulating new practices with sensitive and reflective vocations in

[31] For example, what would a “poster session" be like *for* the arts, revisited *by* the arts? Keeping in mind that poster sessions are usually a meeting time organized during major academic conferences, with large posters synthesizing research, like those that can be found in the corridors of experimental science or engineering science laboratories. In front of every one of the posters, researchers associated with the work in question are present to address any questions or comments. As supports for information as much as discussion, such posters enable the rapid launching of scientific discussion.

tune with the future of our societies by increasing the knowledge about and conditions of such practices; such may be one of the major goals of Research & Creation as we conceive of it. While art has for several centuries[32] been focused on the figure of the artist embodied by his mark on unitary and perennial objects, research in art requires a rethinking of the organization of our institutions to teach creators to say “we” without denying their “I”, and even enhancing its status, albeit differently. This is not an easy task. To meet that need, our institutions must take into account new ways of doing things together and producing something shared, producing a commons. Because, indeed, if it is a question of doing and practicing together, our communities are permeable and do not stop at the doors of the studio or the lab: sharing can take place between peers, with experts in other disciplines, with amateurs, and with an audience. Art, experimental as well as experimentable, is a vector of porosities and connections that make it possible to build audiences and, more broadly, society.[33]

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[32] Albrecht Dürer's founding act - his head-on self-portrait painted in 1500 - comes to mind, as do the major figures of modern and contemporary art whose names have also become labels or brands.

[33] Echoing the book by Didier Debaise, Xavier Douroux, Christian Joschke, Anne Pontégnie, and Katrin Solhdju (Eds.) [28].

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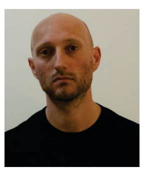

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Closely related to his research and artistic practice, Samuel Bianchini has undertaken theoretical work, which has led to numerous publications with, for example, Éditions du Centre Pompidou, MIT Press, Analogues, Media-N - Journal of the New Media Caucus, Hermes, Les Presses du Réel, Springer, etc. He recently co-edited, with Erik Verhagen, *Practicable: From Participation to Interaction in Contemporary Art*, MIT Press, 2016, with Emanuele Quinz, *Behavioral Objects 1 - A Case Study: Céleste Boursier Mougenot*, Sternberg Press, 2016, and, with Mari Linnman, *À Distances - oeuvré dans les espaces publics,* les Presses du réel, 2017.

CHAPTER 13

The Aesthetic Experience of Time, in between the Hourglass and the Self

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This chapter interrogates time and presents the results of an ethnographic study in a railway station in the suburbs of Paris. More in particular, it analyses the interactions of some of the passengers with 'Texel', an experimental artistic dispositive composed of a number of hourglasses that responds to the movements of the passengers. The study identifies several processes and conditions that explain why some passengers did interact with Texel, while others did not. Subsequently, it explores aesthetic experiences realized during the interaction of people with the device. It focuses on the passage from "aesthetics of perception" to "aesthetics of operation", and on interactive works of art creating such aesthetics. It observes that this takes place in spaces in between the internal experience of the passenger and the external reality of the artistic device, and that this aesthetics is transdisciplinary as it integrates cognition, emotions and enacting. Finally, the chapter explores some links between aesthetic experience and transdisciplinary hermeneutics, and between intermediary spaces of experience and Nicolescu's concept of the Third Included.[1]

Keywords*:* Interactive art, aesthetic experience, transdisciplinary hermeneutics, time, intermediary space of experience, third included.

13.1 Introduction

Time is an objective phenomenon. It can be measured in quantitative units like hours, minutes, seconds, years or decades. Our clocks tick at the same speed every-

[1] This text is also published as the online article: Dieleman Hans, Francesca Cozzolino and Anne Bationo (2017). The aesthetic experience of time, in between the hourglass and the self, Transdisciplinary Journal of Engineering & Science, Vol. 8.

where on the planet and because of that, time exists outside, and independent from us. Yet time is also a subjective experience. As the expression "time flies when you are having fun" indicates, our experience of time is contextual. When we have fun, times goes fast, when we have to wait, it goes slow. It is not at all objective, but precisely very subjective. Time can also be measured, or experienced, in terms of events, or periods, before, during and after. It is the experience of time, and time itself, that is central in this text.

We are interested in experiencing time and more in particular, and the concept of aesthetic experience, which we see as a conscious experience, full of significance. Aesthetic experiences have transformative potential as they have the power to redefine our understanding of the world, truth, relevance, or simply: reality. We want to explore if aesthetic experiences also have the power to change our understanding of time, and we are interested in the role of art in provoking such aesthetic experiences and new understanding. We will introduce "Texel", an artistic and experimental dispositive produced by the French *Forum Vies Mobiles*,[2] and designed by Lyes Hammadouche and Ianis Lallemand, within EnsadLab, the research laboratory of the French National School of Decorative Arts in Paris.[3] Texel was realized as an installation in the Ermont-Eaubonne railway station in the residential area of the Val d'Oise, in the suburbs of Paris, in the period of November 16 to December 16, 2015.

We present the results of an ethnographic study carried out by Anne Bationo, Francesca Cozzolino and Clara Lamireau-Meyer. Anne, Francesca and Clara studied the interactions between the passengers of the train station and Texel, during the period mentioned. They wanted to know if Texel changed the passengers relationship with time and under what conditions such changed occurred. They identified several processes and conditions, such as singularization, the change from time as a flow to floating time, taking an active stand vis-à-vis Texel and estrangement or defamiliarization [1, 2]. We explore the links that exist between the concepts of aesthetic experience and transdisciplinary hermeneutics, and conclude that aesthetic experiences are essentially transdisciplinary. We observe that an essential element in both is that they work with a space in between, combining emotions with cognition allowing us to have conscious experiences, full of significance. We also identify some areas where one concept can learn from the other.

13.2 Texel, a Work of Art That Interrogates Time

The art installation "Texel" interrogates time. The work is composed of a number of interactive hourglasses, conceived in a modular logic. Each module consists of an hourglass of approximately forty centimeters long, placed in a Plexiglas frame with two metal arms, a motor and a sensor (see Figure 13.1). Each module reacts to the movements of the public. By default, the hourglasses are held in a horizontal position, preventing the flow of sand. When a person comes close enough to an hourglass, the hourglass moves slightly, rotating a few degrees forward or backward, starting the movement of the sand. If the traveler moves away from the module, the hourglass returns to its horizontal position, stopping the movement of the sand. But if, intrigued, he or she advances towards the module, the hourglass continues its

[2] www.forumviesmobiles.org

[3] http://www.ensadlab.fr/fr/forum-vie-mobile/

Figure 13.1: Texel, with passenger and detail of one hourglass (Source: Bationo, Cozzolino and Lamireau-Meyer, 2016)

rotation, bowing all the more as the spectator approaches him. The device combines automatism, mechanics and sensors, and relies on an allegory: the flow of sand represents the course of time.

The creators of Texel were interested in particular aspects of time, notably time and movement, and time and place or, in other words, in the complex "time-place-movement", present in specific ways in a railway station. This constitutes a double relationship, that of Texel influencing the experience of time-place-movement in the railway station, and that of the railway station influencing the experience of time-place-movement vis-à-vis Texel. It is this triangle of the artwork, its public and the physical environment in which experiences take place that was interesting the creators of Texel, and the researchers investigating the interaction of the public with Texel. A poster, placed above the installation on top of the artistic credits, accompanied Texel:

> "*Time has replaced distance as the standard of displacement. It is timed with extreme precision and often experienced as a time-out rather than full and subjectively appreciated. The interactive installation Texel questions these perceptions of time and travel in the station.*"

Texel fits into several artistic traditions, like an epistemological tradition in which artists made time the object of various proposals, criticizing in particular the determinism of temporality. As Elie During shows in his book "False Connections, the co-existence of images"[4] [3], many of these artistic projects give shape to particular experiences of time, questioning determinism and linearity. This ranges from videos that play with the expansion of time, made possible by the use of slow motion (like those of Bill Viola or Michel Snow), up to locative media, who question the idea of the omnipresence of ubiquitous and pervasive computing systems. Instead, they focus on the production of localized interfaces that are functionally bound to a particular locations or space-time.

[4] The correct title is: Faux raccords. La coexistence des images. The book is not available in English

Figure 13.2: People passing by without seeing Texel (Source: Bationo, Cozzolino and Lamireau-Meyer, 2016).

Texel above all fits into the tradition of interactive art, based on the notion of interface, relationship and inter-action [4]. As such, Texel is representative of the research carried out in EnsadLab, and especially the group working on Reflective Interaction.[5] It can be seen as a paradigm of contemporary art that proposes to rethink the role of interaction in aesthetic experience. It focuses on an extension of such experience, from an experience merely based on visual perception towards an experience routed in action and interaction. In other words, it explores the passage from "aesthetics of perception" to "aesthetics of operation". Participation is no longer thought of as simply activating dynamic devices but assumes true social value. The beholder of the work of art is not only part of the work's environment, but is a true participant in action [5, 6, 7, 8, 9].

In this paradigm, artists create artistic devices or dispositives that rely above all on strategies to capture, model, or even program behavior and integrate them into objects, to foster aesthetic experience, rather than to perform a technical function. In the case of Texel, interaction is not a form of manipulation to make the work "operative", as switching a button on or off; it rather is a condition to make the work act, as in inter-act. The interaction is mutual. Texel makes the passer-by "act", and not only in an instrumental way. Texel modifies the trajectory of displacement of the passers-by, who in turn make the hourglasses act. Interaction must be understood here as the operative relationship between people and things, between people and people, between things and things. In this, it is the work of art that places the viewer in the position of a practitioner; that is to say, he or she is not in a contemplative posture but part of a particular arrangement of agency [10].

[5] http://diip.ensadlab.fr/en/

13.3 Mass, Flow, Time, Movement, Place, Slowdown and Opening

In their ethnographic study, Bationo, Cozzolino and Lamireau-Meyer explored various aspects of this particular arrangement of agency created by Texel, as well as of the complex "time-place-movement", within the railway station of Ermont-Eaubonne. They observed the movement of the passengers on different moments, like on peak hours during weekdays, outside peak hours and during weekends, and were particularly interested in the interactions of the passengers with Texel. During the period of Texel's exhibition at the station, from 16 November to 16 December 2015, they conducted observations and interviews during 20 half days, switching between what they called a psycho-phenomenological and an ecological perspective. Within the ecological perspective, they studied the movements of the passengers as a group, and the relations between all the variables in the station, like the people, their movements and particular objects within the station. This was done especially to study the working of the artistic device in the particular context of a station. Within the psycho-phenomenological perspective, they studied the experiences of passengers in relation to Texel.

The researchers observed first of all that the station as a whole functions like a dispositive, in which people act in particular ways to realize certain patterns of, particularly, time, space and movement. They observed clear synchronizations between the rhythm of the passengers and the rhythm of the station. During the weekdays and in the rush hours, the population is predominantly between the ages of 16 and 50. The ebb and flow of users of the station is at a very steady pace: every 10 seconds the flow is reversed. The users move in a sustained cadence forming a compact mass, creating a general pattern of ebb and flow: a small herd arrives at the top; the most athletic ones are engaged in a sprint. Then groups of dozens of passengers follow, moving at a race pace as well. Subsequently, there are a few clusters of less hurried people, like "a young woman and her bike" "a man with a backpack" "three women chatting" [11]. At the end of each very dense group, one or two people come running very quickly from the entrance of the station, trying not to miss the train. 90% of the users use the corridor without stopping while looking at the timetable / platform and train displays installed in the passage (see Figure 13.2).

In this way, the Ermont-Eaubonne station processes on average 35,000 passengers per day, passengers who are usually rushing without being open to see and experience anything outside of their main orientation to catch a train. In this group or configuration, it could be said that passengers are already connected to the productive world of work before they even arrive at the workplace. The interviews carried out confirmed this view. Like the 50-year-old lady who mentioned that she passes here every day but that "usually she does not pay attention" or the man telling "I have never seen the installation Texel because I run too fast to catch the train like everyone else" [12].

The passengers join a mass engaged in racing, they "de-singularize" to join a flow that pours all to their workplaces. This de-singularization goes hand in hand with a wider environmental impermeability, with a focus narrowing down on time-flow-movement that constrains the passengers, leaving no room for the unexpected, or for reflection. Very much as Ulrich Beck described, reflection has made way for reflex [13]. People act in reflexes, without thinking, without reflection. In the station, this is very much interlinked with another phenomenon. The passengers form part of a flow, which has relevance in two ways. First it means becoming part of a group, a mass, and secondly it means being part of a movement, a moving mass. What the researchers noticed during their study is, that becoming attentive the Texel (and eventually engaging in aesthetic experience) required both a movement of re-singularization, as well as a movement of slowdown. To switch from reflex to reflection to aesthetic experience seems to imply a movement towards becoming a singular individual again, who “has” time and is not “running out of” time.

Out of peak hours, the situation changes considerably, as is to be expected. Passengers arrive by cluster in much quieter ways than earlier in the morning. The range of ages is widening, with older people entering, visibly retired. People cross the corridor quietly. Some stop in the hall just before the corridor in order to watch the station display, or to wait for companions. *Flow* gradually converts in *floating*, and more precisely in floating time [14], because people have time to wait for a train, and their journey is an activity of predilection (the church, an exhibition, a walk, a restaurant with relatives...), which does not fit in the world of productivity. Under these circumstances, they are more open to walk around, make a detour, being attracted by the peculiarities of the environment. Time as a flow of objective units makes way for time as a sequence of events, while the passengers, in a manner of speaking, sail at the whim of the events that arise along the way. Moreover, these passengers, at that moment, are singular beings connected to their universes of predilection, a universe that favors a de-focusing, and allows for a greater porosity with the vagaries, and the unexpected fruits of wandering. They, at that moment, live in a floating space-time, which allows for a personalized intermingling of the rhythm of the singular world and the rhythm of the station. This being in floating space-time facilitated the encounter with Texel.

13.4 Aesthetic Experiences and the Intermediate Area of Experience

What happened, after passengers were individualized and open enough to meet Texel? Could their encounters be characterized or qualified as aesthetic experiences? Before answering these questions, we need to define better what an aesthetic experience is. We look at an aesthetic experience as a conscious experience, realized when someone is fully aware of what is happening at a certain moment. It is not superficial, but by contrast full of significance. It touches upon notions of meanings and values, and has transformative and creative power as it can change certain meanings and values, and can (re)-create notions of truth or of reality [15]. Aesthetic experiences equally are truly transdisciplinary, as they involve (or are the result of) interaction between emotions and cognitive thinking processes. As Nelson Goodman argues, in aesthetic experiences, there is a heightened operation of both cognition and emotion working together, and more in particularly in the words of Goodman, one feels “emotions functioning cognitively” [16]. In terms of the transdisciplinary concept of Basarab Nicolescu, this means that in aesthetic experiences, we perceive the world over various levels of reality through transdisciplinary hermeneutics, integrating emotions, senses, subjective experiences and formal knowledge [17]. This allows us to experience complexity, and to create a fusion between a subjective and objective notion of reality [18, 19]. Near the end of this chapter, we will come back to this link with transdisciplinarity.

As Sacha Kagan rightfully argues, aesthetic experiences can arise in everyday life, and not only in the confrontation with works of art. However, he continues, artistic creations are especially conducive to aesthetic experience, as they touch upon senses, cognition and emotions in multifold ways, and deliberately seek reflection [20]. The interesting aspect of Texel is, that it combines the two. It seeks aesthetic experience in daily life, yet provoked by a work of art. What is crucial for us is, that aesthetic experiences have as much to do with the activities of 'observers' as with those of 'creators', or as Goodman expressed this, a work of art is never guaranteed to "work" [21] . This depends on the spectator's abilities and attention, as on the environment and the circumstances for contemplation. For Goodman, art only exists if there is a meeting with a visitor able to understand and see. Kagan sees this in a similar way, yet formulates it in slightly different words: "whereas an artist may realize an "art product", it is only through the dialog between the "art product" and the observer that a "work of art" arises"; for to perceive, a beholder must create his own experience" [22]. As mentioned before, in the paradigm of the EnSadLab in Paris, where Texel was designed, the notion of dialogue has been replaced with - or specified towards - that of interactivity and operation. The question if the encounters with Texel led to aesthetic experiences therefore must be answered in particular in terms of the interactions of passengers with Texel vice versa.

This question of interaction was central in the ethnographic study carried out by Bationo, Cozzolino and Lamireau-Meyer. They applied the work of the British pediatrician and psychoanalyst D. W. Winnicott, and more in particular his concept of the "intermediary area of experience" [23, 24]. Using this concept opened an interesting way to look at aesthetic experience, and allowed for the comparison with transdisciplinarity, and especially Nicolescu's concept of the "third included", as we will emphasize near the end of this chapter. Winnicott defines the intermediate area of experience as follows: "In the life of every human being, there is inner reality, an external reality and a third reality, while the intermediate area of experience contributes to shape and reshape simultaneously the experience of the inner and the external life. Thus the intermediate area of experience arises in the interlacing of the worlds: initially between the baby and the mother, then between the child who becomes an adolescent and the family, gradually between the individual and the society. Winnicott emphasizes the importance of objects like dolls that function as intermediates between the "I" and the world in early childhood [25]. It is through such objects that the relationship between the "I" and the "thou" or the "it" is being defined, through experiencing them, interacting with them while attaching symbolic meaning to them (Winnicott speaks of third objects that include also persons). According to Winnicott, we keep exploring and defining reality in between the "I" and "it" throughout life, in intermediate areas of experience using objects, thus exploring and testing various possibilities of seeing and defining reality.

Such experiences are most intense within the realms of the arts, science, religion and imaginative living in general, and Winnicott sees those spaces as places of coming and going where new forms of presence constantly reconfigure themselves to the world and to others. It is therefore fair to say that aesthetic experiences are realized in intermediate areas of experience, which can be characterized as areas of dialogues or interactions between the beholder and the object of beholding. Bationo and Cozzolino [26] studied such areas of intermediate experience, placing them in the context of the characteristics of the station, and the characteristics of the groups of passengers in the station. The first distinction they made was, following the work of

[27], distinguishing the passengers in two groups, those who were open and those who were closed to the experience with Texel. As we saw, the majority of the passengers remained closed for the reasons previously outlined. It cannot be said however that all who were open, entered an area of intermediate experience and that those who did, all realized an aesthetic experience. For the last to happen, people need to really enter in a dialogue or an interaction, as a way of engaging in an experiment that opens a space of possibilities.

13.5 Defining Texel or Exploring Texel

When passengers were individualized and open enough to meet Texel, the events that enrolled could indeed be characterized in terms of entering in intermediate areas of experience and aesthetic experience, but this was not true for all. Various configurations could be distinguished. Some took time to look at Texel, defined it in a certain way, and then moved on without interacting. Part of the passengers that approached Texel, defined it in affirmative ways: it is this or that. Some defined Texel at a kinetic level, through its movements, often related to the flow of passengers, the movement of the passing trains, or the time the doors are open. Others made observations like "It's an hourglass, I think connected to the movement of the train, and vehicles that come out of the station" [28]. Sometimes the association was made with other technological devices installed in stations such as sites to recharge mobile phones. In most of these qualifications or definitions, passengers attempted to bring Texel closer to the productive and quantitative logic of the station. Others attached meaning to the movement of hourglasses, making references to television or even the Bible. It reminded some of the hourglasses used in television debates, to measure the time between two interlocutors. Another mentioned: "We, all humans, are in the hourglass ... in the Bible there is a passage that compares us to grains of sand" [29].

Characteristic for this configuration is, that the initial openness of the passengers towards Texel was of short duration. The mere act of defining, instead of entering in an experiment to explore, closed the meeting almost immediately. This equally was true for those who defined Texel in a negative way. Like some high school students who, after reading the poster, laughed and said: "this is useless, it is an attraction for the stupid". In a conversation that developed with one of the researchers, they continued making similar remarks: "I do not do not understand the principle, for me it's not art, it's a trap for fools" [30].

Another configuration showed real interest in Texel, without being able to define it, yet didn't reject Texel. Like a mother and her son who were waiting for the bus and took the time to wonder, moved round and laughed at the contact they made with Texel. To the researcher present at that moment, they said "We did not know how it moved, we moved to check it, we saw that it moved in relation to our movement and as soon as we stopped, it flipped back in its original position, as if it calculated the time of the person before it. Or like the engineer, interested in technique. "It interests me, I'm an electrical engineer, it's original but I have no explanation ... I think I'll stop tomorrow or after tomorrow if I'm late again ... I'll try to think for myself what it can be and maybe, later, I will read the poster" [31]. Characteristic for these people is that, even though they are open to exploring the device, they define Texel as a mere external reality, and their definitions do not

Figure 13.3: Passenger dancing in front of Texel (Source: Bationo, Cozzolino and Lamireau-Meyer, 2016).

include themselves or involve their own internal reality. In such cases as well, no intermediary area can be created. This changes when a relational experience with the work is realized.

Intermediate areas are created when a relational experience with the work is realized, and this as well happened in the train station. In a number of cases, passengers were interacting with Texel for up to 80 seconds, walking back and fourth, approaching the installation, moving back again, etc. The researchers measured this, using cameras to record movements of passengers in front of Texel, thus complementing qualitative observations and interviews with quantitative data. In this way, they were able to record discoveries of Texel, in intermediate areas of experience. In these cases, passengers no longer defined Texel as something outside of them, but incorporated in the experience their own life stories, biographical expressions, denunciations of stressful work situations, and memories of the past. Memories provoked by Texel, like those of a couple of elders who talked in the interview about their lived experiences of the stations in the years 1960-1970, or a girl remembering her youth in Africa [32].

Characteristic of these moments is their joyfulness and playfulness. Some started to dance in front of Texel, inviting the installation to be their dance partner, to provoke movement and respond to that movement, as in a real dialogue or dance (see Figure 13.3). In such moments, Texel no longer described the world (time, the station, etc.) as a constative statement, but functions as a real performative entity, having an impact on the experience of reality at that moment. Participants were no longer occupied by time; they were giving meaning to time, in interaction with Texel, through joint operation. In such moments as well, a genuine area of intermediate experience in between the external and the internal reality emerges. In those intermediate areas of experience, passenger engage simultaneously in various worlds, their actual worlds, worlds of the past, imaginative dialogues/worlds with Texel creating possibilities of new worlds. In such moments, the conditions for aesthetic experience are being fulfilled, and passengers did have such aesthetic experiences. They created and recreated reality; their experience was full of significance and meaning, transforming their memory of the past and their experience of the present.

13.6 Floating Time, Interaction and Art as a Device of Defamiliarization

Time and interaction appear to be crucial in creating conditions for aesthetic experience, while the two are entangled, and the entanglement is deepened by the characteristics of the artistic dispositive Texel. The passengers creating the moving masses are subordinate to time, which they perceive as a perpetual flow. They move in function of time, which is bigger than they are. They not only fear running out of time; they are literary lost in time, as the standard for displacement. Time for them is linear, measurable and objective, and they subjectively experience it as something to constantly catch up with, to constantly rally behind. The passengers that experimented with Texel, on the other hand, possessed time and occupied time. They were masters of time, defining it and giving it meaning.

Following the French philosopher Elie During, who coined the concept of floating time, we can also say that they experienced time as a sequence of events with specific durations [33]. They were mastering a "floating time", defined by During as a tangle or a bundle of durations. During sees time as a co-existence of durations with some form of simultaneous disjunction and connection between them. Time is therefore one, yet multiple and complex. Not all events and durations communicate with each other, and neither are they absolutely separate; there are degrees of separation. This complicates the co-existence of events and durations (and time as such), but equally opens up space to escape time. The passengers that form the different configurations previously mentioned, can switch configuration. Those who danced with Texel in one particular moment may, in other moments, by part of the moving mass, vice versa.

This disjunction of time - from acceleration to deceleration to acceleration again, from flow to floating to flow again – was crucial, but what makes people change from one to the other? External time constraints are obviously very important, and cannot be ignored. In rush hours, most passengers simply don't have time to interact with a work of art. Yet, outside of rush hours, other factors become important. As we saw, those who defined Texel, either in an affirmative, non-affirmative, positive or negative way, quickly lost interest, and their initial curiosity quickly vanished. Those who entered in a relationship of indetermination with respect to Texel however, remained curious. Indetermination therefore can be seen as a second important variable favoring – eventually - aesthetic experience. Not all who were indeterminate however entered in an experiment with Texel, but those who did certainly started from a position of indetermination. Indetermination is a necessary but not a sufficient condition, as it can remain a rather passive state of mind, which is not followed by entering a purposeful experiment, and possibly an aesthetic experience. For this to happen, it is important to take an active stand, which can be a mere mental or cognitive stand, and an embodied stand as in enacting or interacting with the work of art.

Taking an active stand can be seen, following the work of the literary theoretician of the Russian formalist school Viktor Shklovsky, as allowing oneself to enter in a process of defamiliarization or estrangement, of estranging us from what we are accustomed to perceive [34]. It is a process of awakening from the usually rather functional way of seeing the world and ourselves, as unfreezing a frozen perception based on the habit of taking the world for granted. Being a theoretician of literature, Shklovsky, emphasizes the importance of language as a way of engaging us in the process of defamiliarization, and distinguishes among artistic language and everyday language. Prose is ordinary speech – economical, easy, functional - which causes an individual to function as though by formula, in an automotive mode. Artistic language, like poetry, is imaginative and imagery and because of that, intensifies and energizes reality, estranging the reader from everyday functionality. Russian formalism saw literature – and eventually all art - as a device applying certain techniques, which embody the capacity to provoke estrangement, including estranging the reader from him or herself.

As a device, Texel indeed "deployed" certain techniques - the hourglasses, the sensors – and functioned outside the mere instrumental, as in poetry instead of prose. The purpose of the creators of Texel was close to that of estrangement, as it invited passengers to take distance, and to defamiliarize from the fixed and frozen way they normally see a station, time, movement and displacement. It explicitly looked for a multiple rupture of frame, one with respect to the station, a second with respect to the time of travel in the station and a third with respect to one's own presence in the station. In order to make this happen, movement and interaction was a requisite.

The interaction with the hourglass was followed by a reinterpretation of the hourglass, and eventually time. This interaction allowed passengers to think of time no longer in mere functional and linear terms, but in terms of events and duration. Even though passengers who engaged in Texel were already in a floating time, this floating times deepened as the result of the interaction with Texel, leading them to rethink themselves, in terms of for instance reviving events of the past. Passengers who really engaged in a relational and operative experience with Texel entered in logic very different from the day-to day functional logic of a station, a logic that can be characterized as imaginary and reflective, creative and joyful.

Crucial was interaction and enacting. The switch from "prose to poetry" only was realized through interaction, dancing with Texel, as a true "aesthetics of operation" instead of "aesthetics of perception". In other words, it was no longer the beholder of the work of art that made art "work", but it was the enactor who made the work of art act, while the work of art simultaneously made the enactor act. It is a joint man-machine enacting within a specific arrangement of agency, with the aim of performativity, creating an aesthetic experience of reality in real time. This depended on a set of particular characteristics, such as those of the public or participants of the artwork (openness, indeterminacy, estrangement), the availability of time (floating time and time as a flow), and the wider context in which the interaction with the artwork was realized (the train station). For art to work, all these variables play a crucial role, in an entangled way. They favor or hamper aesthetic experience, in the case of Texel aesthetic experience of time, in between the hourglass and the self.

13.7 The in-between, Aesthetic Experience and Transdisciplinary Hermeneutics

Aesthetic experiences have many dimensions, characteristics, and conditions to be fulfilled for their deployment, as the experiences with Texel show. One characteristic is their transdisciplinarity, which we want to explore in further detail in this last section of the text. According to Goodman, in aesthetic experiences emotions work cognitively. There is a heightened operation of both cognition and emotion, while we experience them *working together.* They create a reality that is no longer subjective or objective, emotional or rational, real or perceived, but a reality in which all of these elements and their apparent contradictions exist together and are – somehow - interconnected.

Goodman's notion is in fact very close to Nicolescu's concept of transdisciplinary hermeneutics [35, 36]. Transdisciplinary hermeneutics essentially is a way of integrated and interpretative knowing. It is a process in which we integrate various ways of knowing, more in particular cognitive (conceptual, science-based) knowing with experiential (enacted, practice-based) knowing with embodied (emotional, sensorial, feelings-based) knowing [37, 38, 39] According to Nicolescu, transdisciplinary hermeneutics enable us to give meaning to life, and allows us to relate with reality not only in mere cognitive and sterile ways, but also in emotional and engaged ways. Moreover, it allows us to see in reality not only that what can be perceive in mere sensorial ways, but it equally allows us to see imagined and felt realities, and combine those. Nicolescu questions on a very fundamental level the contradiction that we normally see between reality and fantasy. What we consider to be reality is always an interpretation, in which we use certain ideas, categories or concepts that are not "out there" as such, but that we subscribe to reality. Such interpretations are loaded with that what we assume, imagine, conceptualize or want, and are thus full of "fantasy" as in the Greek word "phantasia", which means "power of imagination, appearance, image or perception" [40].

In aesthetic experience, we experience reality through transdisciplinary hermeneutics. As Goodman mentioned, emotions and cognition work together or, as Nicolescu points out, it allows us to perceive material as well as imagined and felt realities. What we feel and know, imagine and perceive, all interact and creates in interaction an understanding of reality. It provides us with meaning and has transformative potential, as it potentially changes the concept of reality we have.

Comparing aesthetic experience with transdisciplinary hermeneutics makes us also aware of a certain limitation in Goodman's work. Why does he restrict aesthetic experience to emotions and cognition working together? Why does he not include action, enacting and operation? In the concept of transdisciplinary hermeneutics just presented, we distinguished between cognitive, enacted and embodied knowing or, in other words, cognition, emotions and actions. This is not an arbitrary selection, but based on insights of neuroscience. Our brain functions in interaction with our body and integrates what we do, what we feel and sense with our analytical and logical thinking capacities. Body, cognition and action in a particular environment are one [41]. What we can learn from this is that aesthetic experience is a form of experience in which emotions, cognition and action, as a threesome, always *work together.* Emotions work cognitively vice versa, while acting upon works both emotional and cognitive.

This transdisciplinary deepening of Goodman's notion of aesthetic experience equally provides us with a theoretical base for what we previously called the passage from "aesthetics of perception" to "aesthetics of operation". This concept, currently being developed within the research developed in the group "Reflective Interaction" at Ensadlab,[6] implies that the beholder of the work of art is not only part of the work's environment, but is a true participant interacting with the work of art. In epistemological terms this means that the work of art is a genuine and important actor in our understanding of reality, and that the work of art is a co-creator of reality, or of our interpretation of what we encounter in the world [42]. As we have seen in the case of Texel, the interaction, as a form of exploration or operation, was a key condition for aesthetic experience to take place. It is therefore fair to extend Goodman's concept of aesthetic experience to cognition, emotion and action working together, as a threesome [43]. This should be seen as an important deepening of Goodman's work on aesthetic experience.

There are more similarities that lead to mutual learning between the concepts of aesthetic experience and transdisciplinary hermeneutics. Transdisciplinary hermeneutics takes place in spaces that Nicolescu calls "third included" or "hidden third" [44]. Transdisciplinary knowing cannot be reduced to the pure subjective and neither to the pure objective; it takes place in a space in between the subjective and the objective, a space where knowing always involves the *creation* of reality. Nicolescu's concept of the third included has various similarities with Winnicott's concept of the intermediary area of experience, which Winnicott called a third reality that simultaneously shapes the experience of the inner and the external life. So, aesthetic experience, through transdisciplinary hermeneutics, takes place in spaces in between the internal and external experience, or in between the subject and the object of knowing. In this respect, there is an almost one-on-one fusion of the two.

Winnicott's intermediary area of experience has one element though, which is missing in the theory of transdisciplinary hermeneutics, the element of the "third object". We think that the concept of the third object can be a valuable extension to the theory of transdisciplinary hermeneutics, especially third objects as works of art. Nicolescu writes extensively about the importance of art in transdisciplinary hermeneutics, as art works both with what is seen as with what is imagined. In his terminology, art works over various levels of reality and this makes art intrinsically transdisciplinary [45]. Yet, Nicolescu mainly talks about art in abstract terms, instead of art as concrete works of art, as third objects. The introduction of third objects, and especially third objects that work over various levels of reality, like works of art, can help in important ways in making us perceive reality in transdisciplinary hermeneutical ways. The experiences with Texel, as described in this text, show how it was especially the interaction with Texel, as a third object, which made people redefine themselves, their environment and the object they were interacting with. The interaction with third objects, especially works of art, can play important roles in stimulating transdisciplinary hermeneutics, especially when deployed as "aesthetics of operation".

[6] http://diip.ensadlab.fr/en/. See also: Bianchini S. et Verhagen E. (dir.), *Practicable. From Participation to Interaction in Contemporay Art*, Cambridge - Londres, MIT Press, 2016. Bianchini S.l *et al.*, "(Mis)Behavioral object, empowerment of users vs empowerment of objects", in BIHANIC David (dir.), *Empowering Users Through Design, Interdisciplinary Studies and Combined Approaches for Technological Products and Services*, Berlin, Éd. Springer, 2015, p.129-152. Bianchini S. et Fourmentreaux J.P., "Médias praticables : l'interactivité à l'œuvre", in *Sociétés* 2007 / 2, no 96, Bruxelles, Éd. De Boeck Université, p. 91-104.

The experiences with Texel in the context of the railway station, yet points at one more "lesson" to take into consideration when thinking of transdisciplinary hermeneutics. Can, or should we always try to understand and know the world in transdisciplinary hermeneutical ways? Are there restrictions and conditions to be fulfilled that allow us to be transdisciplinary hermeneutical? The answer seems to be that there are, and those conditions probably are very similar to the ones previously laid out with respect to aesthetic experience. A big part of our lives, we need to act in rather unconscious ways, and because of that, habits have their valuable function. When we were supposed to reinvent reality every day, and be aware of complexity all the time, there would be little time left to ensure our survival. The experiences with Texel show us that people open up to reflection – as in aesthetic experience and transdisciplinary hermeneutics – once they can afford to do so. Nicolescu mentions that it doesn't make sense, and is even dangerous, to question the objectivity of the world around us all the time, like when we are driving a car in traffic. Yet, as the experience with Texel, it is possible to create "niches of time" within day-to-day life, for reflection, as in aesthetic experience and transdisciplinary hermeneutics. Such niches are very valuable and certainly should be stimulated and advocated.

Finally, we like to point at one last way in which transdisciplinarity can contribute to our understanding of aesthetic experience. Aesthetic experience is not only seen as a conscious and meaningful experience full of significance, but is often seen as well as a way to realize a fusion with the world, enabling us to be "one" with the world in a holistic sense. This way of looking at aesthetic experience has been rather common in the literature, and was particularly strong in the use of art in nature studies and sustainability, stimulated by Suzi Gablik's influential book "The Reenchantment of Art" [46]. Gablik looked at art almost as a tool to re-establish a Romantic fusion with nature, as a countervailing power against de disenchantment of the rationalized world. In his article "The end of aesthetic experience", Shusterman concludes that seeing aesthetic experience as a (romantic) fusion of a person with the surrounding world contributed in considerable extent to the loss of interest in the concept of aesthetic experience. Nowadays, he argues, "it may seem very "retro" to suggest that aesthetic experience can function something like an empathy box" [47]. In an attempt to rescue the concept of aesthetic experience, he emphasizes once more its meaning as" heightened, meaningful, and valuable phenomenological experience" and as a directional concept, "reminding us of what is worth seeking in art and elsewhere in life" [48].

What we want to emphasize, taking transdisciplinarity in consideration, is the following. A fusion with the world, felt in moments of aesthetic experience, does not imply a feeling of wholeness that eliminates contradictions and ambiguity (as in romantic fusion or harmony). On the contrary, it may make us feel and experience wholeness as complexity, acknowledging that the way we know and relate to reality creates multiple understanding of reality. It does not integrate objective and subjective reality, like objective and subjective time, through reducing the one to the other, but makes us experience – or know, or become conscious - that both exist at the same time, while neither one can be reduced to the other. It is this complexity that, we like to argue, is worth seeking for in art and elsewhere in life, as a countervailing power against simplicity and one-sidedness, so strongly present in contemporary societies.

13.8 Conclusion

There is objective time and there is subjective time, as there is an objective and a subjective world, in which we both live. Each have their own logic and in moments of aesthetic experience, through transdisciplinary hermeneutics, we are able to integrate these dimensions and experience complexity. Passengers of the Ermont-Eaubonne railway station, while interacting with Texel, were masters of floating time yet remembered memories of the past, belonging to linear time. Even though the interactions with Texel were events of limited duration, they exceeded that duration as they integrated events of the past. The notions of time as duration and time as a linear flow did not dilute, but went hand-in-hand without any problem. The passengers identified Texel - at first - as a world outside of them, yet created an intermediary reality in between Texel and themselves, which overarched the contradiction of the subjective and the objective, or the internal and the external. Texel became part of them, while they became part of Texel, while neither of them disappeared.

Certain conditions need to be fulfilled, while objects and interaction with those objects seem to be crucial. Works of art, which speak the language of poetry instead of prose, facilitate defamiliarization from everyday reality. Interaction makes works of art act, while those interactions simultaneously make the enactor act. In both aesthetic experience as in transdisciplinary hermeneutics, action and operation is crucial, to realize what we also might call, aesthetics of transdisciplinarity.

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