



Maturity model of transdisciplinary knowledge management



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ABSTRACT

In this article a maturity model for the management of transdisciplinary knowledge is presented, although research nowadays is transdisciplinary the different maturity models proposed in the literature are oriented towards interdisciplinary knowledge management, and, at most, they are oriented toward multidisciplinary knowledge management. The objective is proposing an evolutionary model which accepts knowledge as intensely active and dynamic and evolving in maturity from the early stages of research. But this is possible only if the research team adopt a clear, clean and joint process of disciplinary integration and transdisciplinary integration of the produced and discovered knowledge. In this way, the results of research will have a greater influence on society and they also will be adopted by society.

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1. Introduction

Promoted as an adequate scientific answer to significant social problems, transdisciplinary research has a long history of scientific-academic discourse. However, despite his growing support and popularity it is still far from become established academically and scientifically as a field having large support in universities and research institutions. One of the reasons is that an accepted universal definition has not been promulgated until now. As a consequence, the quality standards that researches, software administrations and financial backers could meet are still insufficient (Serna & Serna, 2013). Therefore, it remains in the rhetoric field, and those who consider it seriously and perform integration efforts have the risk of be marginalized. It is necessary to find common principles and subjects in the discourse of the transdisciplinary research; identifying the characteristics of a comparative framework; presenting conceptual models that can be used for the scientific policy in order to characterize the different types and their demands related to integration; and defining maturity models to manage the emerging transdisciplinary knowledge.

In that sense, an international group of scientists warned that the future of science depends on the funding of the transdisciplinary scientific collaboration (Vasbinder, Nanyang, & Arthur, 2010). They argue that science based on outdated methods that preserve and reinforce the disciplinarity, does not properly understand the ways in which the complex technological developments of this age interconnect themselves and influence society. Expressed

sions like this remember us that in spite of many years of debate inside science and scientific policy, the new cultures and practices of transdisciplinary scientific collaboration are not yet established. Based on this and other perspectives at first sight it seems that transdisciplinarity is a concept hard to reach, in fact we do not already have a definition universally accepted even after half a century of intense academic discourse. However, when the concept or ideas are not defined correctly we must face the risk that superficial interpretation prevails; and the latent danger is that the true challenges of the transdisciplinary research become underestimated and that people who consider them seriously become marginalized. Besides being unable to identify a consensus about which constitutes transdisciplinarity some crucial issues remain controversial:

- 1) Still there is no agreement about whether transdisciplinary research is a new and different type of production of knowledge. In that sense, Zierhofer and Burger (2007), analyzed some projects reported like being of transdisciplinary research, and they did not found a single plan that allowed classify them as such based on an epistemological or methodological perspective; therefore they concluded that according to this point of view they do not appear to be new and different types of production of knowledge. Emphasizing that transdisciplinarity do not has a critical evaluation of new knowledge, which is constitutive for the production of scientific knowledge, Maasen and Lieven (2006) argue that transdisciplinary scenarios are useful for mutual learning, but not for joint research. In the field of the necessary discussions to help the positioning of transdisciplinarity, these and others arguments deserve a careful

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consideration. Because denying the transdisciplinary the status of irrefutable mode of production of knowledge can, on the one hand, seriously deteriorate the necessary attempts for establishing it inside academy, and on the other hand, placing it outside academy would be prejudicial to the efforts made for defining widely accepted quality criteria for transdisciplinary research. The latter is a fundamental tool for the management of transdisciplinary knowledge and for the expectations of involved people, which can contribute to the progress of the work in concrete social and scientific problems.

- 2) If transdisciplinarity is a new mode for managing scientific knowledge is a recurrent subject in the discourse. In this sense, Nowotny, Scott, and Gibbons (2001) affirm that transdisciplinary research not only must produce true knowledge, but also socially robust knowledge. Answering to this, Maasen and Lieven (2006) argument that this is related to what mainly an individual researcher does in order to produce quality results by reconciling different standards and disciplinary approaches, but having different extra-scientific requirements. From a perspective of individualization of responsibilities, this authors warn that transdisciplinarity is a new way of knowledge management that involves procedures of social responsibility. This critique emphasizes the fact that, because this new relation science-society, the functions and responsibilities of scientists change radically. However, this changes still have neither been discussed enough in literature, nor even are reflected suitably in research practice, and there is not a model of maturity that allow the management of produced knowledge.

In summary, the transdisciplinarity is the research approach best adapted to face the complex problems that scientific development itself produce continuously, and, in fact, it is mainly related to the relation scientific-society. Besides, it is interventionist, because methodically structures, organizes and place the social discourse of a specific predicament. In this model and, in addition to their traditional tasks, a special role is assigned to science: the transdisciplinary research must manage and differentiate the different types of knowledge, because they clarify the way in which knowledge is produced and how is related to the web of complex interconnections. Essentially, the transdisciplinarity is both critical and self-reflective, because it examines not only the systematic way for producing and using knowledge, but also the different actors that support it. Besides, it methodically challenges how science itself deals with the resistance between searching of the true and the increasing demand for result of utility.

This paper has two objectives: on the one hand analyzing how transdisciplinary knowledge is produced, disseminated and used, and on the other hand proposing a model of maturity for managing it. Besides, this article is derived from a necessity identified in different researches performed by the author with people of different disciplines, but in which a true teamwork has not been accomplished, without subordination and power. The proposed model of maturity for managing transdisciplinary knowledge has been thoroughly validated in a transdisciplinary-multinational research, in which the author participates successfully.

2. Transdisciplinarity

The fact that the meaning of transdisciplinary is still a debate does not imply that could not be found contributions that intensify the discussion, on the contrary, an analysis of the definitions proposed until now reveals several trends (Pohl & Hadorn, 2007):

- 1) The definition usually progresses from interdisciplinarity passing through multidisciplinary until transdisciplinarity. It is a

progression because for each x disciplinarity it goes beyond than the last in a scientific aspect, and it can be part of the rhetoric definition instead of an objective necessity (Klein, 1990). Jantsch (1970) considers this progression as the degree of coordination between education system and innovation, with all the system spinning around a general objective called progress or ecological balance. For Rosenfield (1992), this progression is found in a shared conceptual framework share, where interdisciplinarity means that researchers of different disciplines use their respective methods, techniques and capabilities for facing a particular problem. In such a case transdisciplinarity is a force which encourages to people representing different disciplines to transcend their conceptual, theoretical, and methodological individual orientations with the objective of developing a common research approach, based on common conceptual framework. Lawrence (2004) sees the progression in the bodies of knowledge and the social groups involved. For this author interdisciplinarity implies a joint mixture of disciplines, while transdisciplinarity implies the fusion between the disciplinary knowledge and the know-how of lay people. Therefore, while this definitions share the idea of a progression until transdisciplinarity, they differ in the principal characteristic of this progress.

- 2) The definition only describes a series of characteristics of transdisciplinarity, it describes that transdisciplinarity focuses in subjects of social relevance, that it transcends and integrates disciplinary paradigms, that it turns research into participatory, and that it searches the unity of knowledge beyond disciplines. According to the importance of this characteristics different definitions are structured (Cerrosen & Pong, 2012). For example, the research is transdisciplinary if it transcends and integrates disciplinary paradigms in order to deal with socially relevant questions (not academically). This type of research is necessary because the processes of specialization of knowledge production are driven by internal scientific-disciplinary interests (Boleros, 2013), that progressively move away from social problems and needs. Brewer (1999) opines that this is like the world have problems, but the universities have departments. The production of academic knowledge, organized from a disciplinary perspective, must be re-organized and re-evaluated from the perspective of relevant social questions (Jantsch, 1970; Rosenfield, 1992; Mittelstrass, 1993).

Transdisciplinarity means widening the above concept including non-academic actors through a participative research. In this sense, Gibbons et al. (1994) and Nowotny, Scott, and Gibbons (2001) identify a new type of production of knowledge, that complements the traditional linear model in which science proposes, society disposes (Guston & Sarewitz, 2002). This model is developed within the context of the application of knowledge, which is opposite to the traditional academic ivory tower. The process of production of knowledge includes the interested parties from science, society, private and public sectors. In the American context, the function of participatory research is not commonly attributed to transdisciplinarity, therefore Stokols (2006) calls this mode of production of knowledge as one of transdisciplinary action research, representing a participatory approach. At the end, the research becomes transdisciplinary when includes a search of unity of knowledge, which is not a purpose itself. The main objective consist in reorganize the academic knowledge whit the purpose that it become useful to deal with socially relevant subjects. However, the knowledge is neither re-organized nor re-evaluated in a pragmatic and eclectic way, instead of this with the development of a comprehensive or perspective point of view that goes beyond all discipline. Based on this point of view is that socially relevant subjects are structured, ana-

lyzed, and processed in a second stage (Nicolescu, 2002; Ramadier, 2004).

3) The society plays a very important role in this new perspective of research and scientific cooperation, because the transdisciplinary knowledge must be re-contextualized for a wider audience coming from multiple disciplines, becoming more accessible and interpretable (Hunsinger, 2005). For Charles Kleiber (2002), transdisciplinarity means to share and disseminate the disciplinary knowledge and information, the technological revolutions, and the creation of networks and new ways of knowledge. Due to the global nature of current problems, which cannot be solved by persons or individual groups, the researches should involve others sectors of the society (Häberli & Thompson, 2002). Additionally, since knowledge is transgressive, transdisciplinarity does not respect institutional boundaries (Gibbons & Nowotny, 2002); therefore, it crosses national borderlines because it is a transnational concept. Thence it means something more than a sum of researchers of different disciplines working together, as in the case of interdisciplinarity or multidisciplinary. Other aspect is that it also crosses the academic boundaries with the objective of solving real-world problems. The universities and other research organizations must be open-minded and be ready to cooperate with non-academic people and with scientists belonging to other disciplines. In this understanding everybody can learn from the other, because collaboration in a transdisciplinary work require actors which open the horizons and which participate of science in order to contribute with new ideas and points of view, for both knowing better the real world and the proofs and the adaptation of their theories (Häberli & Thompson, 2002).

Epistemologically, the transdisciplinary is based on three fundamental pillars (Nicolescu, 2006): (1) the levels of reality, (2) the principle of the third included, and (3) the complexity. Additionally it recognizes the rational and the relational as simultaneous modes of reasoning. Therefore, the transdisciplinarity represents a clear challenge to the binary and linear logic of the Aristotelian tradition. In the course of human evolution the transition from spoken communication, with knowledge disseminated through histories and myths, to written communication, the primacy of rational thinking over relational thinking became the rule. The result has been that the fascination produced by the reason is so big that have become lost other abilities and sentiments which made easier the understanding of the nature from inside. Morin (2008) refers to this when designed his building of knowledge, which allows to learn managing knowledge based on the different sources and dimensions in which is produced. From other perspective, transdisciplinarity operates tightly related to the impacts of thinking of Paulo Freire and Leonardo Boff. The Pedagogy of Oppressed of Freire (1970) can be considered like a challenge to the economy and to the development models driven by technology based on disciplinary scientific knowledge. This author understand literacy not only in terms of reading words, but also like reading the world, which means that promoting critical conscience in the people is an important content for developing the world itself. This change in the understanding of development become deeper when was associated to Liberation Theology of Boff (1986), as a specific methodology to work with people.

3. Transdisciplinary knowledge

Informally is affirmed that science produces many and different types of things, and that it provides to society the technological means to control the nature and the cultural world. Besides, is also

said that science is the basis to produce power and elitist structures which contribute to their own interests or to perpetuate the political status quo. However, if is conceived as a social institution is reasonable and legitimate to wait that it produces reliable and important knowledge to solve any type of social problems (Merton, 1942; Weingart, 2001). Kitcher (2001) complement this affirmation by observing that science could fight epistemically and legitimately for giving practical importance to the production of knowledge. In this way it is more reliable if is produced under systematic methodological restrictions. In fact, transdisciplinary research is conceptualized to ensure that the choice of scientific problems generate knowledge which would have influence on the most important needs of Knowledge Society.

Commonly, scientific knowledge is associated to propositional knowledge, that is to say, this represented in prepositions such as $A \in B$ or $X > Z$, and similar. This notion of knowledge was developed in epistemology, where it is defined explicitly as justified, guaranteed, or reliable. But from cognitive integration it refers to a notion of justification, and represents the central element of the concept of knowledge defined in that way. For this reason is used the expression production of scientific knowledge for alluding to the knowledge that is restricted by systematic methodologies, that is to say, by justifications and standards. Besides, we must accept that the affirmations of scientific knowledge refer explicitly to very specific subjects, and therefore presuppose some type of ontological commitment (Quine, 1948). In this scenario, the scientific specializations can be basically an object of discrimination, among other things by the specific characteristics of their methodological and ontological models. In addition, since all the affirmations of knowledge come from some discipline, the transdisciplinary research must meet this restriction, therefore basically the cognitive integration refers to the integration of the heterogeneous demands of scientific knowledge, and, in this particular case, of the integration of their methodology and ontological guidelines.

Apart from this notions of transdisciplinary knowledge there are other notions which have been discussed in epistemology, for example, the notion of Russell (1912) of known knowledge, or the discussion of Ryle (1946) about of knowledge-how, in contrast to the knowledge for what, that is to say, the propositional knowledge. While these and other notions still are discussed in the contemporary epistemology, the scientific identification of propositional knowledge do not have still the same attention. In any case, in fields like science sociology the notion of propositional knowledge is adequate for the analysis of the integrational cognitive tasks and for the transdisciplinary modes of production of knowledge. The problem which faces this notion is that it has not been still defined explicitly, and that does not exist a general consensus from the epistemology and the philosophy about the science regarding it. However, this not distorts its analytical advantage related to the transdisciplinary knowledge.

In any case, the transdisciplinary integration of knowledge can occur in the context of both the integrated evaluations and vulnerability of the scientific knowledge. Although this integration is fundamental to design a model of knowledge management, the real process rarely is addressed explicitly and methodologically. In this work it is conceptualized based on the stages to its production and by using a shared language and proper of methodological design, and through a series of devices: (1) the semantic rise or change of language, to talk using a meta-language about past issues (2) the formalization or translation of the declarations in ordinary or technical language into formal language, and (3) the methods of integration of knowledge, which provide the meta-language to refer the knowledge to be integrated and organized in the model of management.

Since knowledge is a mental category which refers to the relation between the beliefs of an individual and the external world,

we must avoid certain epistemological issues and to move away from the nature or certainty of such relation, because the knowledge in this way is characterized based on the belief that it is true and just (Plato, 1921). Instead of that, the best is to consider its external representation, that is to say, the linguistic expressions produced by the people which have knowledge (Carnap, 1938). Besides, a characteristic quality of scientific knowledge is that it can be represented and communicated orally, visually, or in a written way. For this are useful the meta-languages developed from a disciplinary basis, and it is also possible studying explicitly the knowledge and its representation, as in science philosophy, the Computational Science, didactics, semiotics, and linguistics.

Based on these developed meta-languages, meaning must be given to the integration of transdisciplinary knowledge. In order to achieve that, and because as we have already expressed above it must be respected its disciplinary origin, is necessary to develop a shared language and to design a methodology which lead to integration, comprehension, and to communication. In this process we must consider that in the integration of transdisciplinary knowledge lessons must be learned of failed attempts, like this of logic empiricism (Neurath, 1938) and this of the General System Theory (Bertalanffy, 1968), because the objective is to re-establish the unity of science, that is to say, to establish a scientific theory for the transdisciplinarity that have wide acceptance. The difficulty faced by this and others attempts it was to try to fit the languages, the theories, and the disciplinary methods like the pieces of a puzzle (Kitcher, 1999). The reality is that each discipline abstracts the physical world in a different way, because they only select the necessary aspects and abandon the other (Jaeger, 2003). In this way they focus on a little number of aspects in order to solve their problems in the complex world. Additionally, by their own nature, the languages and the theories have as objective to simplify the real world for a specific purpose, therefore they have a limited range. In contrast with this unitary vision of science, the transdisciplinary problems integrates the local knowledge, both pragmatic and specific, in addition to the dimensions in which it originates and the complex variables defining it.

In the transdisciplinarity knowledge does not exist in the absence of dialogue. Either through socio-cultural interactions, through the exchange with peers, or because it is extracted from nature the knowledge is accumulated through the bidirectional exchange of information. Without this dialogue there is no transmission, revision, management, or expansion because they are inherently reflective, dynamic and transdisciplinary processes. If not shared, any knowledge will be sterile and will be condemned to forget, and this knowledge will neither mutate nor evolve; besides, similarly to others live systems, the mind need cross-bred fertilization in order to maintain its vigor. For this reason the transdisciplinary knowledge gets strengthened in the constructive exchange between disciplines and through the assertive and structured management. The theory basis that support the principles of the transdisciplinarity, which have bring to light a possible crisis in the management of knowledge, emphasize the need of a research which interrelate science, multiple disciplines, and scientists to address the complex problems of this century. It is not only the quantity of knowledge which is produced but: who has access to it? What are its power relations in society? How a transdisciplinarity research will be able to adapt it and incorporate it into a changing world? And, how can you manage to turn it socially useful?

It might be considered that a multi-disciplinary approach is enough to overcome this crisis in knowledge, and is possible to argue the work made by many teams, for example, for preserving environment. But these teams do not talk to each other significantly, and they are limited to perform sub-processes whose results are reported to their coordinator, and they do not know their influence on the final result, because they simply do not talk. An

interdisciplinary perspective can also be used, with the same group of scientists working around the same subject, but they really do not have a permanent communication. Therefore, the complex problems and crisis of knowledge management need a transdisciplinary research approach, with a wide range of scientists work immersed in the community, developing appropriate initiatives of research and design, searching to solve problems and which help to link evidence with action. But there are relatively few successful examples of this type of work.

In this way, the activities of creation of knowledge would involve the discovery of new information, because there is a transdisciplinary research team which get involved in an exploration of knowledge, attitudes, and practices related to each particular problem. This team works together, and, through dialogue, discover and strengthen knowledge, which is properly managed to positively contribute to solve social problems. That is to say, they work with society and not in spite of society. The problem here is the lack of social capital prepared for this kind of research (Levison et al., 2011). Therefore are needed models to manage the transdisciplinary knowledge, that allow to know their level of maturity and that by means of creative and socialization activities would provide confidence to the community.

4. Maturity model of transdisciplinary knowledge management

Considered from a rational and empirical approach what is important in the management of transdisciplinary knowledge is their functionalist perspective, because it allows to know about the rational world while integrates the disciplines and individuals as substantial components of scientific knowledge. The point of view here is that scientific knowledge generated in a transdisciplinary way is achieved through the sharing of the bodies of knowledge of individual disciplines and the experience of each participating individual. But we must add to this universe the knowledge that is discovered or produced in the research process itself, therefore it is intrinsically indeterminate but socially needed (Serna, 2012). This is why the transdisciplinary research is performed with society and not for society.

From this perspective the knowledge does not exist in advance, waiting to be discovered, but this type of research analyzes it, experiment with it, and reflects about it before presenting it, because it is assumed that is required an interaction between the disciplines, the experiences, and the society (Serna, 2011). For this reason, even the simplest knowledge experiences a complex social process, where researchers interpret the world and learn from it through social interaction (Daft & Weick, 1984). Additionally, transdisciplinary research emphasizes in social action within the practice, because this action is fundamental to understand the acquisition of knowledge and its usefulness for the community. Furthermore, through a participatory action within the social context meaning is created. A maturity model for managing this knowledge should emphasize on the discovery of knowledge within the research process through exchange social interaction, and in this way knowledge acquires importance and demonstrates its usefulness within these structures. Once incorporated to society knowledge is disseminated through dynamic processes governing communities. In this way knowledge emerges from shared actions and complex multidimensional processes, and is promulgated in the practice of people. For this reason, from the perspective of transdisciplinary research emphasis is made on practice, to indicate that in a specific moment what practice and dissemination have done, which is achieved through mutually constitutive actions of it.

In addition to these considerations, in the management of transdisciplinary knowledge, knowledge should be considered as an

Table 1
Levels of the affective dimension (Bloom, 1956).

Reception	Researchers, as individuals, are passive; they know how to listen and they perceive emotions; they are motivated by knowledge; without this level it cannot exist knowledge generation.
Answer	Researchers work in teams and are active in the process of knowledge; they attend to disciplinary stimuli and react and assign value judgments to what is discovered or constructed.
Assessment	The researchers assign value judgments to knowledge shared from other disciplines.
Organization	Researchers are organized as a transdisciplinary team to create and organize a system of value; they prioritize knowledge; they solve disciplinary conflicts; and they create a unique system of validation and verification of transdisciplinary knowledge.
Characterization	Researchers define the system of implementation and use of knowledge in society; they construct a scale in order to assess its influence on communities; and they disseminate the knowledge they have validated and verified.

active object, because it is embedded in recurrent human practices surrounding the research, and because if knowledge is static it would not be transdisciplinary. Transferring knowledge from one place to another does not mean that it is a moving object or only because it is transmitted, encoded, or disseminated, but knowledge reaches this mobility because is a product permanently embedded in any scientific activity and because their actions and human representations are shown and found in social contexts (Venters, Cushman, & Cornford, 2002). When transdisciplinary research is performed to build and discover knowledge, the social nature of knowledge is emphasized, what must necessarily lead to a management focused on social interaction rather than on cold information. This is why this vision considers that knowledge is a continuous achievement and a process rather than an isolated object, because it is dynamic and not static. By observing knowledge from this perspective we emphasize on concepts such as construction of meaning and community of practice, because its rationale is constituted by social practices of creation and application.

A maturity model to manage this knowledge should be evolutionary in nature, that is to say, structured in a series of progressive stages in which the complexity increases until reaching a perfect inclusion in society. This type of maturity models in the management of transdisciplinary knowledge is characterized by constructing optimal multidimensional scenarios, which reflect during the development stages. Traditionally is accepted that a model with these characteristics should consist of five stages or levels in which knowledge evolves progressively: biased, reactive, appreciative, organized, and optimized (Serna, 2012). But, although this model is similar to those proposed in other fields, in transdisciplinary research it requires certain management components assigned to the maturity scale, such as people management, process management, technology management, disciplinary knowledge management, and management of social benefit, in addition to managing the cognitive dimension of the learning based on Bloom's taxonomy (1956), because from this point of view is possible to consider the semiotics of knowledge process.

This taxonomy uses a system of values that can be adapted to manage the behavior of single disciplinary knowledge, considered from affective and psychomotor dimensions. The first is related to how people share levels of feeling, values, positions, enthusiasms, motivations, and attitudes about the construction, discovery, and use of knowledge (Table 1). The second provides a perspective in

Table 2
Psychomotor dimension levels (Bloom, 1956).

Perception	Researchers develop skills to guide motor activity towards the integration of disciplinary knowledge.
Disposition	Researchers are willing to act from their disciplinary skills, and they plan actions to understand and interact with other.
Directed response	Researchers develop skills to give guided answers to the requests of knowledge from other disciplines.
Automatic answers	Researchers develop skills to present answers to society regarding transdisciplinary knowledge.
Conscious execution	Researchers create patterns of responsibility to incorporate knowledge in communities and in new environments.

which what is important is not the different objectives of knowledge but its hierarchical levels (Table 2).

4.1. Maturity model operationalization

4.1.1. Predisposed level

The research team has adequate capacity to respond or attend to the knowledge generated from individual disciplines. Some members might become specialized in order to listen and to respond to the needs but they are restricted to their disciplines. The team lacks of abilities, skills, and appropriate capabilities to perform the activities of psychomotor dimension, because their perception of knowledge integration is poor and team members do not know the sources of knowledge of other disciplines. It is possible that individually they know them properly, but always within a particular disciplinary context. The team has a low capacity of perception, therefore the team do not adequately responds to the difficulties of integrating knowledge. This because, at this level, and as a team, researchers do not have the ability to develop mechanisms, complex responses, adaptations, or to participate in the creations required by disciplinary integration, and although there are trained individuals to lead them, as a team they do not yet reach that.

4.1.2. Reaction level

Investigators respond to external pressure to improve disciplinary knowledge management and they initiate strategies to address and respond to interdisciplinary information sources. Individuals better manage the information coming from different disciplines and initiate interdisciplinary interaction processes. At this point, is possible that as a team they do not perform the full integration, but some individuals begin to get tuned to the management of interdisciplinary knowledge, though is still difficult to them recognizing relationships of information coming simultaneously from several disciplines. At this level is expected that the researchers improve their perception and willingness to act and respond to the information flowing between disciplines.

4.1.3. Evaluation level

The team evaluates the need of transforming information into knowledge, and start managing multidisciplinary agreements and this of transverse and horizontal analysis in order to achieve a better evaluation of the information and the relations that allow processing it, give it meaning, and manage it as knowledge. The research team increases its range of perception, improves its willingness to interact, and begins to mature their ability to manage knowledge from a transdisciplinary perspective. This because researchers

Table 3
Operationalization of the maturity model of transdisciplinary knowledge management

Levels	Characteristics Resource management	Analytical administration	Significant administration	Active management
Predisposed	• The researchers individually have their own resources and responsibilities to manage the information they require from their disciplines. • Not all the disciplines are interesting for the team. • It is poor the value, volume, and content of information.	• There is no standard definition for disciplinary information. • Each researcher defines the sources of information. • The analytical assessments of the team are of low quality and are not portable. • The analysis generated from each discipline are not harmonious or compatible with the other.	• The researchers interpret individually the information. • The performances are incomplete and are not shared effectively with other disciplines. • The team takes action without verification. • Team comprehensive knowledge is neither produced nor applied.	• Any action is based on individual premonitions. • There is no predisposition for feedback between disciplines to monitor the effectiveness and efficiency of disciplinary information.
Action	• Subgroups are created based on related disciplines in order to find convergence in the usefulness of the information. • Definitions and conceptual maps are created to start the standardization of a process of discipline management. • Disciplines are integrated within subgroups. • Researchers from each subgroup structure tools to retrieve and integrate interdisciplinary information.	• The subgroups standardize procedures to regulate the analysis, deployment, and management of interdisciplinary information. • It is achieved efficient and effective transformation of interdisciplinary information in each sub-group.	• Interpretations in each subgroup are standardized. • A common language is structured to manage interdisciplinary information. • Each group exchanges, compares, argues, integrates, and actively feeds back interdisciplinary information. • Reports and progress indicators are improved.	• Actions inside subgroups are based on the agreed interpretations. • Efficiency of operations is increased and information exchange makes flexible. • Feedback from interdisciplinary information is restricted to the subgroup.
Evaluation	• Alliances between subgroups start. • Integration and management of multidisciplinary information is promoted. • Definitions, mind maps, and the efforts of management of multidisciplinary information are exchanged. • The mechanisms for the analysis, retrieval, and representation of the multidisciplinary information are shared.	• Subgroups share analysis processes and exchange of multidisciplinary information. • Analysis processes are redefined and each involved process is better understood. • The information analyzed in a multidisciplinary way increases its scope. • The volume of multidisciplinary information increases and the repositories grow and become more sophisticated.	• Meanings and functions are shared. • Partners-translators are defined in order to structure the necessary syntax and terminology for managing multidisciplinary information. • The subgroups start to consider the multidisciplinary information coming from the other.	• Alliances between subgroups are created with multidisciplinary related information. • Forms of action are extended and experiences are shared. • The context of interpretation of multidisciplinary information is expanded. • The efficiency and effectiveness of multidisciplinary management is increased.
Organized	• The team develops a repertoire of transdisciplinary information. • Mind maps are examined in order to enable their convergence and to solve potential conflicts in transdisciplinary information. • The team develops a standardized architecture to retrieve transdisciplinary information. • The team has a wide mind map of the disciplinary information.	• The team is capable of perform transdisciplinary analysis based on an appropriate definition of transdisciplinary information and their integration elements. • It is structured and implemented in the team a repository in order to promote the reuse of the analysis of transdisciplinary information, and continuous monitoring and feedback cycles are defined.	• The levels of analysis of transdisciplinary information are increased and are shared with members of society. • Starts knowledge production from transdisciplinary information. • The team manages the diversity of languages and encourages and promotes the transdisciplinary dialogue based on social meanings.	• The team designs unique actions for the management of transdisciplinary knowledge based on meanings. • Is created a repository of actions and answers to make easier the reuse of existing disciplinary knowledge. • A procedure is designed in order to assess the influence of disciplinary knowledge in the social context.
Optimized	• The team recognizes, respects, and actively promotes the transformation of disciplinary information into transdisciplinary knowledge, and routinely update the procedures to achieve this. • The transdisciplinary mind map is updated and continuously adjusted in order to reflect the dynamism of disciplinary knowledge created and/or discovered.	• The team is committed to search more effective ways to evaluate transdisciplinary analysis before implementing the knowledge in society. • Mechanisms are designed to rationalize the processes of generation and application of transdisciplinary knowledge.	• The research team put into operation procedures to make easier the continuous review of the meanings, advantages, and disadvantages of transdisciplinary knowledge. • It is created and observed the commitment for training social agents. • Mechanisms are designed to maintain the efficiency and effectiveness of disciplinary knowledge and its social implications.	• The structures of management of transdisciplinary knowledge is constantly improved by considering the multidimensional and complexity of social contexts. • Are continuously updated the pre and post-assessments to the actions of implementation of transdisciplinary knowledge in society. • The team has a repository of actions to use and to add to the body of knowledge all the information generated from the disciplines.

learn to interact through activities of multidisciplinary knowledge management, and start to develop and to structure activities and instances in order to meet the complex demands of the management of this knowledge. To perform this, they need to coordinate their management activities through the development of abilities, skills, and capabilities to manage knowledge from the multidisciplinary to the transdisciplinarity.

4.1.4. Organized level

The research team is organized by means of an architecture around the transdisciplinary knowledge, and begins to implement resource management, analytical administration, significantly administration, and active knowledge management activities. Now the research team is able to perform all the management activities structured for the transdisciplinary knowledge, that is to say, perception, willingness to act, guided response, activities of mechanisms, of complex answers, and activities of adaptation and creation, which results in the understanding and total transformation of multidisciplinary knowledge into an active transdisciplinary knowledge that all researchers understand and can transform into a social good.

4.1.5. Optimized level

The team manage to discover and to adapt individual similarities between their concepts of personality and character development to manage knowledge transdisciplinary. Teamwork benefits from openness to the continuous improvement of knowledge management, and relies on the practices, abilities, skills, and capabilities of individuals to positively influence society. This hones individual's adaptability, creation, and knowledge discovery. Their goal now is to reduce the time of knowledge adaptation and to increase the fluency and the skills to put into the required social contexts.

In the Table 3 are summarized the levels and characteristics of the operationalization of a maturity model of transdisciplinary knowledge management.

5. Conclusions

The management of transdisciplinary knowledge is a research strategy that must be planned from the formulation of any line of work, whose social benefits depend on many factors. A maturity model to manage it is essential for any team of researchers and must be marked among its activities. In this work is described a maturity model that combines the strengths of knowledge management and that is oriented to strengthen the social benefits of transdisciplinary research. This model is highly flexible due to its concept of design and because it can be adapted to any research environment. It is used a balanced approach between the traditional conception of interdisciplinary and multidisciplinary knowledge, and its necessary evolution towards transdisciplinary knowledge. Although focused in strengthening the disciplinary knowledge, the objective is to maximize the benefits of each of them, considering key areas, processes, technologies, and products to mold the best way to make them useful and solid when implementation time arrives. The final maturity level considers the target community, along with partner communities, as a joint venture. Hence the model can be extended from traditional to global in order to achieve a proper management of transdisciplinary knowledge produced in any research.

The analysis and design of the application of transdisciplinary research show significant challenges. For example, the issue regarding how much disciplinary control is assigned in a transdisciplinary process is crucial because it influences the balance of power among researchers. In addition, agreements and disagreements among researches, the products, and social organizations are defined in relation to specific aspects of how to incorporate the entire process of research and its products. Although scientific and non-scientific

actors share a common objective and a set of values about managing resources, these differences clearly represent different perspectives on transdisciplinary research.

In contrast to the interdisciplinary or multidisciplinary researches in which the control, authority, and the results are clearly defined, in the transdisciplinary research they must be incorporated as activities in the action plan. In this way a maturity level is obtained from the process formulation itself. Therefore, initiating and controlling the implicit process of transdisciplinary research must not be assumed as a position of power, because this results in asymmetries that could potentially prevent the necessary equality to progress in the different levels of the model. As described in this paper, this is possible because the process of evolution to transdisciplinarity is planned, but favoring a balance between flexibility and joint coordination, and conducting negotiations at all the levels of the maturity model. Issues as control, balance of power, and analysis of the immersion of disciplinary knowledge in communities have been addressed marginally in some research, but in this model they are involved from the beginning, and they are managed through the progress in the level of maturity.

This is very important in order to achieve the objectives of transdisciplinary research, in the sense that it is not only a part of the community which benefits from the immersion of knowledge, because this is the interdisciplinary and multidisciplinary approach, instead of that the whole process must be done based on disciplinary collaboration and cooperating with social agents. In this sense, it is important to note how the epistemological debates about scientific objectivity provide ideas and arguments about how to deal with disciplinary research positions. These points of view are considered in the proposed model, because they show that every individual researcher, and that social actors, have a specific contextualization that makes easier, while restricts, transdisciplinary knowledge management. In addition, these theories provide arguments to break the barriers of disciplinary work in research and knowledge production that are feasible to implement and to use in a maturity model of transdisciplinary knowledge management. Another issue proposed here is that transdisciplinary research, as such, must consider secondary actors, that is to say it must consider to the non-researchers, because in this way is achieved a better understanding of the social and disciplinary order and of the structures that limit their participation. In this way is achieved a deeper and better appropriation of knowledge and of its benefits and social impacts.

Because of the potential for social transformation of transdisciplinary research, and because of the knowledge it produces, in the maturity model is also involved the complex and multidimensional processing of knowledge; another issue that is rarely discussed in the transdisciplinary literature. A model like the proposed, and in relation to objectivity and standard compliance and ethics of application, is less controversial regarding the effectiveness and benefits of scientific research. In part, because society is involved in the whole process, but especially because the researchers know everything about everyone because there is no single authority but a collaborative work.

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