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# NANOTECHNOLOGY AS A PRIVILEGED EXAMPLE OF TECHNOLOGICAL INNOVATION: BUILDING FOUNDATIONS FOR THE DESIGN OF THE "QUADRUPLE HELIX"

*LA NANOTECNOLOGÍA COMO UN EJEMPLO PRIVILEGIADO DE INNOVACIÓN TECNOLÓGICA: CONSTRUYENDO LAS BASES PARA LA CREACIÓN DE LA "CUÁDRUPLE HÉLICE"*

*NANOTECNOLOGIA COMO UM EXEMPLO PRIVILEGIADO DE INOVAÇÃO TECNOLÓGICA: CONSTRUINDO AS BASES PARA O DESENHO DA "HÉLICE QUÁDRUPLA"*

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**Abstract:** A nanometer is a billionth part of a meter. It is in this order of magnitude, ranging from 1 to 100 nm (1 to 100 nanometers), that an effective Scientific Revolution is situated. The results of this research benefit laboratories through to industry, turning into products in a variety of segments, which are already available for consumption. Thus, nanotechnology emerges as the most significant example of innovation in recent times, which promises to change people's lives and becomes the scenario for the creation of unprecedented new rights. This is the context in which the emergence of a new concept of innovation is projected, built through the arrangement of a quadruple helix: University, Industry, State and Human Rights. It is important to give the text of the Legislation of Innovation of the State of Rio Grande do Sul a hermeneutic meaning, using the legal model that is closest to the proposed quadruple helix.

**Keywords**: Nanotechnology. Philosophical Hermeneutics. Quadruple Helix. Human Rights. Innovation Law.

**Resumo:** Um nanômetro é a bilionésima parte de um metro. É nesta ordem de grandeza, variando de 1 a 100 nm (1 a 100 nanômetros), que a Revolução Científica está posicionada. Os resultados desta pesquisa partem de laboratórios até as indústrias e transformam-se em produtos de diversos segmentos, para então estarem disponíveis para o consumo. Assim, a nanotecnologia surge como o exemplo mais significativo de inovação dos últimos tempos, que promete transformar a vida das pessoas e é o cenário perfeito para criação de novos direitos. Este é o contexto em que o nascimento de um novo conceito de inovação é projetado, construído por meio da combinação de quatro hélices: Universidade, Indústria, Estado e Direitos Humanos. É importante dar ao texto da Legislação de Inovação do Estado do Rio Grande do Sul um significado hermenêutico, utilizando o modelo legal que mais se aproxima da proposta da hélice quádrupla.

**Palavras-chave:** Nanotecnologia. Hermenêutica Filosófica.

Hélice quádrupla. Direitos Humanos. Lei de Inovação.

**Resumen:** Un nanómetro es la billonésima parte de un metro. En este orden de grandeza, variando de 1 a 100 nm (1 a 100 nanómetros), se ubica la Revolución Científica. Los resultados de esta investigación parten de laboratorios, van hasta las industrias, y se transforman en productos de diversos segmentos, para quedar entonces disponibles para el consumo. Así, la nanotecnología surge como el ejemplo más significativo de innovación de los últimos tiempos, que promete transformar la vida de las personas y es el escenario perfecto para la creación de nuevos derechos. Este es el contexto en el que se proyecta el nacimiento de un nuevo concepto de innovación construido por medio de la combinación de cuatro hélices: Universidad, Industria, Estado y Derechos Humanos. Es importante que se le dé al texto de la Legislación de Innovación del Estado de Rio Grande do Sul un significado hermenéutico, utilizando el modelo legal que más se aproxima a la propuesta de la cuádruple hélice.

**Palabras clave:** Nanotecnología. Hermenéutica Filosófica. Hélix Cuádruple. Derechos Humanos. Ley de Innovación.

## INTRODUCTION

The restlessness of the human race leads it to explore uncharted territory. This is the scenario in which nanotechnology is projected; a set of technologies from various areas that manipulate atoms and molecules on a scale ranging from 1 to 100 nanometers. The range of creativity that is opened up with nanoscale research seeks to imitate and recreate nature, where the nanoscale has always existed. However, it is only now that human beings have the scientific and technical conditions to access it.

This possibility creates a true scientific revolution, because nanotechnology does not fit into the standards thus far known and scaled. Nevertheless, there

are also studies, although still incipient, that point out the risks of products that carry nanoparticles. It should be noted that there are chemical changes in pieces that are structured from particles in nanoscale when compared to similar works built in other scales. This scientific context should balance the evaluation of the benefits of nanotechnology, relating them to humans and to the environment. Both humans and the environment will bear the positive or negative outcomes of these discoveries.

This paper will investigate the necessary remodeling of the concept of innovation, which was managed based on the FRASCATI Manual until the conception of the Triple Helix in the terms developed by Henry Etzkowitz. Despite this, it is clearly important to consider another aspect: Human Rights, which will be responsible for the ethical shaping of knowledge capitalization. Therefore, the problem studied can be outlined as follows: under what conditions do does nanotechnology fit the concept of "Innovation in Motion" in the Triple Helix, and indicate the need to include a fourth cell, responsible for the inclusion of an ethical bias?

The objective of this research is to reshape Etzkowitz's concept of innovation, adding an element focused on the substantial perspective brought by the idea of Human Rights, based on the analysis of Brazilian federal law on innovation, and comparing it to the legal text in Rio Grande do Sul, which regulates technological innovation, using nanotechnology as an example to work with the "quadruple helix".

## NANOTECHNOLOGY AND HUMAN CREATIVITY: BIG CHALLENGES WITH A SMALL TECHNOLOGY

As a starting point, demonstrating the great potential of human creativity, we examine the work carried out by researchers at the University of Florida in the United States, who created a molecular nanomotor moved only by photons, the basic particles of light, and made from a single DNA molecule. The nanomotor was created by joining a DNA molecule and a molecule of azobenzene, a chemical compound that reacts to light. A low-energy photon causes these molecules to

react in one way, while a high-energy photon causes a different type of reaction. The size of this human creation should be pointed out: in its closed form, the nanomotor is between 2 to 5 nanometers in size. Under the light, by exerting its strength, the motor opens, stretching to between 10 and 12 nanometers.

According to researchers, the performance of the photonic nanomotor is not high; it is less effective than photovoltaic solar cells. However, its major advantage is the direct conversion of light into mechanical motion, opening the possibility for nanoscale applications that are not possible with the traditional scheme used in macroscale, where electricity is used to power a motor, which does the mechanical work. Another advantage is that because the nanomotor is made of DNA, it is biocompatible, and can be used in developments aimed at applications in biomedicine. Research is still in its infancy, but it is already possible to envision positive aspects, especially in interactions with humans, given its compositional structure.[4]

This is a small example of the possibilities that nanotechnology provides. It is important to note that with the term nano, a measurement is referenced, which means it represents the billionth part of a meter, denoted by the scientific notation $10^{-9}$. According to Dupas, "Nanotechnology is a set of multidisciplinary techniques that allow the domain of extremely small particles (nanoparticles), showing completely new mechanical, optical, magnetic and chemical properties" (Dupas, 2009, p. 57, our translation). The most interesting aspect of research in nanoscale is the potential to build things by manipulating atoms:

> When we go to the very, very small world – say circuits of seven atoms – we have a lot of new things that would happen that represent completely new opportunities for *design*. Atoms on a small scale behave like nothing on a large scale, for they satisfy the laws of quantum mechanics. So, as we go down and fiddle around with the atoms down there, we are working with different laws, and we can expect to do different things. We can manufacture in different ways (Feynman, 2010).

4 Available at http://www.inovacaotecnologica.com.br/noticias/ Accessed on January 2, 2013. Reference used on this page: Huaizhi Kang, Haipeng Liu, Joseph A. Phillips, Zehui Cao, Youngmi Kim, Yan Chen, Zunyi Yang, Jianwei Li, Weihong Tan. *Nano Letters.* Single-DNA Molecule Nanomotor Regulated by **Photons, June** 5, 2009, Vol.: Article ASAP, DOI: 10.1021/nl9011694.

It is verified that the properties and characteristics of things produced by manipulation on nanoscale are different from those that exist in other scales. This is a point of caution, and such changes must be examined due to the risk of toxicity.

The development of nanomotors shows one of the possibilities of construction that humans will be able to develop, "correcting" the "imperfections" that Eric Drexler pointed out: "[...], human beings are very bad, very poor at making things. Almost everything that we could draw and design with atomic precision cannot be done at present. [...] Only now are we learning how to handle and put into place the fundamental pieces of matter that make up everything". (Drexler, 2009, p. 46, our translation). The case of the nanomotor fits Drexler's characterization perfectly. A question arises: what is the limit of the human power of creation to build things? The announcements of possibilities brought by nanotechnology give the impression that everything that humans want can be created and recreated. It must be emphasized that in nature, the nanoscale has always been part of the essence of many things. However, it is only now that humans are accessing the opportunity to develop and design things (materials, objects, products) with nano particles. As I have stated earlier, we cannot overlook the concern for the consequences for human beings and for the environment (Engelmann, 2009 and 2009a).

In a sense, human entry into the world of nanoscale opens the possibility of building "new identities and new spaces"[5], with unknown magnitudes. In this scenario, there are inherently human concerns and ambiguities that can be dealt with through practical reason. A rational attitude that can evaluate the positive and negative aspects is concerned with protecting humans and the environment (Engelmann, 2011). In this context, two possibilities appear: a) each situation must be examined individually, on a case by case basis, weighing the positive aspects and risks, b) the proposition of a moratorium and the adoption of the precautionary principle. "The moratorium on any use of nanotechnology can be seen as a 'harder' way to adopt this principle. In its mildest form, the precautionary principle advocates a preventive action to be taken, even without scientific evidence of causal risks of

5 Expression adapted from SILVA, Marise Borba. Nanotecnologia e a criação de novos espaços e novas identidades. IN: *Cadernos IHU Ideias.* São Leopoldo: Unisinos, year 8, n. 139, 2010, 18p.

nanoparticles" (Martins and Ramos, 2009, p. 50-1, our translation). Neither of the two alternatives seems to be the most appropriate because in practice, they would make the continuity of research, and the production process with nanoparticles that has already begun, unfeasible. The first of these alternatives would require a very large apparatus to get down to the specifics of each case. This might be possible when the manipulation of nanoparticles is in small numbers, but would it become increasingly impossible with increases in nanoscale production. The second option blocks the continuity of research and the production process. This would create obstacles to the advancement of nanotechnological innovation, which is extremely difficult to justify.

The application of the precautionary principle does not allow for the abovementioned positions, because "this principle makes imperative all means that can, for an economical and socially bearable cost, detect and evaluate risk, reducing it to an acceptable minimum, and if possible, to eliminating it" (Lewicki, 2006, p. 361, our translation). It should be noted that the adoption of the precautionary principle does not authorize the complete moratorium of research and the use of nanotechnology. The implementation of the precautionary principle requires care, analysis and rationally justified decisions, rather than an interruption pure and simple. It is important to exercise caution when using it, so as not to detract from the purpose of the principle, which is closely linked to risk management[6]. Consequently, to achieve the precautionary principle, it is essential to manage situations that generate risks by controlling the causes. However, this does not mean, stopping everything that is generating risk in every case. In this context, it is also necessary to include an ethics agenda to guide the precaution that should mediate the tension between positive visions and precautionary actions (Throne-Holst and Sto, 2008, p. 99-100, our translation).

Examining how nanotechnology interacts with technology generated in other scales, it can be classified into two categories: a) the first group is nanotechnology "that promotes incremental innovation", i.e. "they are technologies that manipulate

6 On this theme, see: Engelmann, Wilson; Flores, André Stringhi and Dossena Jr., Juliano. O Princípio Fundamental da Precaução: o Fascínio da Criatividade e os Desafios (Humanos) das Pesquisas com o Emprego de Nanotecnologias. IN: *Anais do IV Workshop em Nanociências da UNIFRA,* held on September 14 to 16, 2009. 1 CD. ISSN 2175-6856.

structures in nanoscale of substances in macroscale, or to put it another way, substances in macroscale that are handled by technologies that interfere in their nanostructures" (Martins, 2010, p. 10, our translation). And b) the second group is "revolutionary innovations promoted by nanotechnology, which include technologies that build mechanisms in nanoscale to be used in macroscale environments" (Martins, 2010, p.11, our translation). In the first group, there are things to be improved, increasing the possibility of their use in smaller quantities, which are lighter and more resistant, along with other characteristics that would be impossible without the manipulation of atoms and molecules. In other words, what already exists will be improved, which is the increment. The second group is considered pure innovation, given the novelty and originality of what will be produced through nanoscale.

Both groups will be responsible for certain effects and characteristics, which could be as follows:

a) In the implementation of incremental innovations of nanotechnology, it is possible that the following situations will be encountered:

> a. The time and environment in which they develop are fundamental, and need to be tackled politically.
>
> b. They affect industry and the political spheres of society.
>
> c. "Differences between previous discontinuities (incremental innovation arising from other technologies) and those arising from nanotechnology, are only levels".
>
> d. "Changes in the industry will always be forced and risky, however, they have already been seen on other occasions".
>
> e. "Policies will be aimed at particular products, and not at nanotechnology itself".
>
> f. Case by case analysis will guide studies and policy proposal.

> g. "The effects will be similar to semiconductors, synthetic polymers, wireless telecommunications, etc." (Martins, 2010, p. 11, our translation).

b) Revolutionary innovations generated from nanotechnology should be guided by the following characteristics:

> a. Society will face unprecedented issues, "by allowing humans to manipulate the world on an unprecedented scale".
>
> b. Nanomachines – like the molecular nanomotor initially described – open a new frontier where there are no regulations that ensure the safety and productivity of this activity.
>
> c. "They have different qualities and properties that will generate new responsibility and control issues, which are linked to three items: invisibility, mobility and self-replication". These aspects will generate new rights in different sectors of society and the environment.
>
> d. "It is necessary to rethink the legal basis and normative structures of society. Three aspects are important: monitoring, property and control". (Martins, 2010, p. 11-2, our translation). This will require the development of a new way of visualizing the Sources of Law, stressing the need for valorization of legal pluralism, and promoting a dialogue between the sources of Law (Engelmann, 2010a).

The issues raised will require decision-making, with attention to various areas such as the economic, political, social and scientific aspects, but above all, considering the positive and negative probabilities in relation to humans and the environment. Therefore, decisions cannot be made without a deep concern for the impacts they generate. According to Gilberto Dupas, it is necessary to resolve the conflict that is established between the freedom of the individual and the hegemonic impositions of society (2009, p. 83, our translation). In this scenario, it seems that the discussions and decisions to be made should include a return to human values, or "the need to resume ethical values as a reference for the discussion about the future of science in general, and of nanotechnology in particular". Hence, "there will be no solution to the main problems of mankind if the public space does not resume control of private interests, and especially not

until we rediscover common human values that can lead our future as a species" (Dupas, 2009, p. 85, our translation). The return to ethical values, regardless of the name it is given, means placing human beings and the environment as essential and non-negotiable points. For this management, standards of public interest should override private interests. It will be necessary to look carefully at the text of the Constitution, which holds the guidelines for community life, which should be applied to individual decisions. This is the guarantee that decisions will be guided by collective welfare, respecting the individuality of each case.

Even though there is no specific regulatory framework, the following characteristics must be considered: the universe continues to be populated by humans, and all questions should be addressed with a minimum civility, guided by "moral feelings of obligation and guilt, censorship and forgiveness". It will be necessary to adapt "practices of the world of life and of the political community to the assumptions of the moral of reason and to human rights", because these assumptions provide "a common base in favor of human dignity above ideological differences" (Habermas 2004, p. 101). There are some guidelines for decision-making that can mediate the great possibilities of nanotechnology. And there is no other humanly acceptable alternative, other than returning to the single element that in essence, does not change, namely, the humanity of human beings.

## "NATURE AS TEXT": POSSIBILITIES OF PHILOSOPHICAL HERMENEUTICS TO THE AXIOLOGICAL INTRODUCTION IN THE CONSTRUCTION OF AN INNOVATION CONCEPT.

The scope of high technological potential cannot underestimate the following aspect: all results – whether positive or negative – will be borne by human beings and by the environment. Thus, we should not forget a supreme ethical requirement: "the irreducible human":

> There is a negation of human beings not necessarily when there is an attempt on life, but when, in one form or another, there is an attempt on what we call, with a severe and profound word, *human dignity*, i.e.,

> that which allows human beings to value themselves as beings with blood in their veins, elevating them to more than just their biological reality, pronouncing a word that they can really take on, by which they can express themselves (Jean Ladrière *in* Delmas-Marty, 2004, p. 185, our translation).

Here we draw some fundamental ethical assumptions for this moment. Human beings cannot be simply seen as something biologically available in a laboratory, a mere material to be studied, reproduced and improved. On the contrary, human beings are something much more essential: a being of flesh, bone, feelings, and a fundamental element: human dignity. This dignity does not project into test tubes, but it is the result of a long and arduous path of tradition with struggles, suffering and conquests, which cannot be reproduced in a laboratory. In other words, it is an effective evolution, which is the result of simply living with other humans, with equal dignity.

It is precisely in this space that the reflection about the binomial "human" and "non-human" should begin, because it reveals "that the evolution of the representation of values of universal vocation is late and undoubtedly unfinished" (Delmas-Marty, 2008a). It involves acts of barbarism that have outraged the conscience of mankind, and that are part of the pre-human understanding. It is precisely the acts against those deemed "non-human" – therefore, available for any kind of scientific research – that should not be forgotten, since this categorization affects human dignity with death. This is the path of tradition in which humans are inserted.

This binomial gets a new reading when the look to "future generations" is debated, including the concern for environment. Thus, it could be stated that "non-human" is an extension of "human", i.e., a healthy environment is necessary for the development of any person. This generates the expression "humanism in relation": "for relations, it would be a way to build a relation, and I speak of legal relation, from human to animal and, extensively, from human to nature" (Delmas-Marty, 2008). It is precisely based on this unprecedented relationship established between human and nature/the environment – between human and non-human – that a new context for the topic of liability arises, out of the so-called "security requirement" (Viney, 2008). Until then, the liability covered only

the relationship between human beings. It will also be possible to plan, using this bias, the inclusion of a "healthy environment" as a new right.

From this scenario, which corresponds to the substantial scope of the fourth helix, arise possibilities for the emergence of "nature as text" (Villarroel, 2006) and of a new philosophy in science (here understood in its broad vision encompassing all areas of knowledge)[7]. The construction of the foundations of this approach – mediated by hermeneutic phenomenology[8] – will be permeated by tradition and language. Therefore, the following warning should not be forgotten:

> [...] That language does not constitute the true hermeneutic occurrence as language, as grammar or as lexicon, but as what has been said in tradition, which is, at the same time, appropriation and interpretation. This is the point at which it can be surely said that this occurrence is not our action in the thing, but the action of the thing itself. (...). (Gadamer, 2002, p. 672, § 467, our translation).

Tradition provides the historical horizon where past events are projected, which should enlighten the development of the justification of scientific knowledge wrought by means of nanotechnology.

In the movement of the hermeneutic circle, pre-understanding precedes the understanding/interpretation/application that will give meaning to the nanotechnological discoveries in which the researcher is directly involved. This same context should envisage nanoscale investigations, based on the researcher's experience, through his pre-understanding of the world, life, and the results of human investments in nature. Human beings, including the researcher himself, have always been inserted in a context where novelties in nanoscale are produced and generate their effects – positive or negative.

7 For more information, see: Engelmann, Wilson. A nanotecnociência como uma revolução científica: os Direitos Humanos e uma (nova) filosofia *na* ciência. IN: Streck, Lenio Luiz e Morais, José Luis Bolzan de (Orgs). *Constituição, Sistemas Sociais e Hermenêutica:* Graduate Law Program Yearbook – Master and Doctorate – UNISINOS, n. 6. Porto Alegre: Livraria do Advogado, 2010.

8 This is also the methodological orientation of construction of the research presented here. It is important to state that the researcher takes part of the context in which nanotechnological research is developed, being exposed to its consequences – whether positive or negative. Therefore, the phenomenon of research on nanoscale is not outside the world to which the researcher belongs. Furthermore, this phenomenal set will receive meaning, from pre-understanding, moving the hermeneutical circle.

Therefore, the hermeneutic situation mentioned by Gadamer has a perfect relationship with the scenario of technological innovation created by nanotechnology: "[...] interpretation has to find the correct language, if it wants the text to actually speak. Consequently, there cannot be a correct interpretation 'in itself', because each case has its own text". There is no reproduction of a case, when there can often be a relationship of similarity between two situations, but not of equality. So, in nanotechnology, case by case analysis must take this detail into account: "[...] the historical life of tradition consists in its dependence on new interpretations and appropriations. A correct interpretation would, in itself, be a thoughtless ideal, unable to know the essence of tradition. Each interpretation is bound to fit the hermeneutic situation to which it belongs". (Gadamer, 2002, p. 578, § 401, our translation). The relationship between humans and the environment projects this kind of situation, which requires (responsible) decisions with specific outlines for each case. Either way, the tradition of the interpreter, of the situation, and of the researchers should be projected into the historical horizon, taking from it what has been learned through past experiences with the use of revolutionary technologies. Hence, the hermeneutics discussed here does not apply solely to the legal field, but to the field of scientific knowledge as a whole, also permeating scientific areas that do not deal directly with these concepts. A paradigmatic case is to consider "nature" as a "text" that should be given meaning in order to continue serving as a shelter (home) to humans.

This is the basis for developing an ethical reflection on the "human-technique-nature" relationship (Villarroel, 2006, p. 173, our translation). To do so, it will be necessary to (re)pose the question of co-belonging between humans and nature, which can go beyond the mere control and domination of the forces of nature by man, as both "[...] can come to need each other [...]", in a kind of "neighborhood between Humans and Nature [...]", where "they exist in front of each other, and each of which inevitably contributes to the proximity of the other" (Villarroel, 2006, p. 185, our translation). There is a relationship between humans and non-humans (nature). It is not, however, a relationship of superiority or priority, but of supportive reciprocity. They need one another, and must therefore respect one another, along with their characteristics and potential.

Humans need to realize that nature, as an occurrence, cannot be appropriated and exploited to exhaustion. The logic must be modified: nature exists to be cared for, because it is essential for human survival. This is the new responsibility of care that humans must learn to respect and consolidate.

Because of this, philosophical hermeneutics also argues that one cannot think of the text as something that might be appropriated; forcing it (the text) to reveal its meaning and scope, but meaning should be attributed to it, respecting its limits. Thus, nature must also receive an attribution of meaning – which is human care and responsibility, in order to continue existing. This is the space for nature to appear as text.

The relationship between humans and the environment is circular. It should always be understood as something in which every human being exists and is one human being. Applying the environment to every human being means realizing the impossibility of human life without the environment. This relationship, however, is not always processed in the same way, because human life is changing, especially due to the reflections generated by nanotechnology, requiring new and appropriate responses to the challenges produced.

In the same vein, there is no man without nature; and nature is nature only through men and their language, as a condition of possibility for the attribution of this sense. Because of this, it should be considered "nature as text", which must be interpreted, cultivated, cared for and respected to generate the norm, that corresponds to the relation of co-responsibility of all men in the preservation of nature.

That is the way to introduce the axiological concept (the fourth helix) into the new outline of the concept of innovation, a fundamental characteristic for reinventing in the context of nanotechnology, and preparing to provide answers that are appropriate and reasonable for modern technology. An ethical paradigm will be needed, such as a thread that permeates the construction of the practice of innovation, in the molds that will be built hereafter, with the following characteristics (adjustment of contributions of Villarroel, 2006, p. 217 *et seq*, our translation): a) ethics that have certain standards of reasonableness that are not utopian but practical, concerned with human action, b) in the structuring of these

ethics, it is necessary to insert a thorough qualification for the environment, and a "requirement of adequacy or belonging" of mankind to this question, c) a concern for the applicability or feasibility that a proposition of this kind should have is essential.

This creates a space for the entry of the Aristotelian model of phronesis, prospected on a contextualized rereading with the current characteristics, notably its use in both "means" and "ends" that men choose to fully carry out[9]. In terms of hermeneutics, the proposal is "open ethics of the human experience" that does not correspond to a "'neutral' description of objectivity" (Villarroel, 2006, p. 213, our translation), but that represents care for humans and the environment, projected into the respect of limits, moderation and the construction of a "middle ground" that is not mathematically in the middle, but at a location where the needs of all generations of human beings – present and future – can be assessed. Therefore, the management of "practical reason", i.e. reason concerned with human action, along with the development of (legal) standards capable of operating this itinerary, will be vital. Special attention to this reason is necessary, because forgetting it can lead to producing monsters, or decisions that are irreversible, damaging the preservation of the humanity of human beings. This characterization is inspired by Goya's etching, entitled "The sleep of reason produces monsters".

Therefore, through phronesis – prudence, moderation, balance and weighing – it will be necessary to realize that "human rights carry a moral or ethical dimension that necessarily depends on a different rationality. And the reverse is also true: universalizing, mobile, evolutional and flexible rationality" (Delmas-Marty, 2005, p. 284, our translation). Practical reason will be the appropriate rationality to account for the challenges that nanotechnology brings with it. Moreover, this rationality should not be neglected, but focused on human action; otherwise, irreversible results may be produced. These irreversible results appear if practical reason is ignored, or is not used for the appropriate practical considerations. It is important to note that the manipulation of a utopian ethics, which is merely theoretical, can generate the monsters shown in Goya's etching.

9 To examine the rereading of Aristotelian *phronesis* carefully, see: Engelmann, Wilson. *Direito Natural, Ética e Hermenêutica.* Porto Alegre: Livraria do Advogado Editora, 2007.

This context of concern arises

> in the lack of distance, [where] everything becomes indifferent as a consequence of the will to secure and empower the totality of earth in a calculating and uniform way. The struggle for domination of land has entered its decisive phase. The full exploitation of land, by securing its domination, is only established when it conquers, off the ground, the extreme position for its control (Heidegger, 2003, p. 168, our translation).

The power awakened by nanotechnology fits this scenario, because this power is in a hurry to get established, and does not allow the required distance for reasonable decision-making on the courses, limits and possibilities of the research. This perspective is exacerbated by the methodology that carries scientific knowledge, which is disconnected from reality, leading scientists to develop their experiences without linking them to the world in which they live. That is why they think they can dominate the entire earth. This is where the phenomenological hermeneutic perspective intends to intervene, in order to show that scientists are part of the world in which the results of nanotechnology will be perceived.

Because of all this, it is necessary to "temporalize", i.e., "to mature, let emerge", that which is processed in the "triple simultaneity" of the time of "the strength of existing, the strength of doing and waiting and the strength that awaits us, which we usually call the strength to come" (Heidegger, 2003, p. 169). Practical reason should be revalued so that rationality is not ignored, but at the same time, the issues relating to the research and results on the nanoscale should be allowed to mature. Therefore, it becomes important to link past, present and future, extracting from this triple simultaneity the learning that has been transmitted by the tradition of human experiences with technologies that have already been experienced.

Consequently, this is the path to the entrance of concern for humans and the environment – an axiological perspective – in the (re)formulation of the concept of innovation that is able to process the positive effects brought by nanotechnology.

# FROM INNOVATION TO THE "QUADRUPLE HELIX": HUMAN RIGHTS AND THE CAPITALIZATION OF KNOWLEDGE

The Organization for Economic Cooperation and Development (OECD) was established by the Convention signed in Paris on December 14, 1960, and entered into force on September 30, 1961. In June 1963, the OECD organized a meeting of national experts in Research and Development (RD) statistics in the Italian town of Frascati. The result of this work was the first official version of the Proposed Standard Practice for Surveys on Research and Experimental Development. This led to the creation of the FRASCATI MANUAL: a technical document that shows the role of science and technology, through the analysis of national innovation systems.

At that time, rapid technological changes and research and development (R&D) constituted an important element for economic growth. The monitoring of R&D efforts in industry, government and universities is the key to performing analyzes and carrying out successful policies.

The Frascati Manual has become the internationally recognized methodological guide for compiling and using RD statistics, and is an indispensable tool in statistical offices around the world. It includes definitions of key concepts, policies on data and ratings to be used in the compilation of statistical data. Through the internationally recognized concepts and classifications of its activities, the Manual has contributed to intergovernmental debates about "best practices" in the field of scientific and technological policies. Technological innovation activities are the set of scientific, technological, organizational, financial and commercial steps, including investments in new knowledge, leading, or attempting to lead to the implantation of products and new or improved processes[10].

As an extension of this Manual, the OECD elaborated the OSLO Manual, first published in 1990. It is the major international source of guidelines for the collection and use of data on innovative industrial activities.

10 Available at http://www.reppittec.org.br/ArquivosUpload/1/File/Manual_de_Frascati.pdf Accessed on January 20, 2013.

The ability to determine the scale of innovative activities, the characteristics of innovative companies, and the internal and systemic factors that can influence innovation, is a prerequisite for the development and analysis of policies aimed at encouraging technological innovation.

According to the OSLO Manual "technological innovations in products and processes comprise the implementation of technologically new products and processes, and significant technological improvements in those products and processes. A TPP innovation is considered established if it has been introduced to the market (product innovation) or used in the production process (process innovation). A TPP innovation involves a series of scientific, technological, organizational, financial and commercial activities. An innovative company in TPP is a company that has implemented technologically new products or processes, or substantial technological improvement during the period analyzed"[11].

In 2006, the third edition of the OSLO Manual was created. It includes the following concept: an innovation is the implementation of a new or significantly improved product (good or service), process, new marketing method, or new organizational method in business practices, in the organization of a workplace or in external relations[12]. The new edition brings a concept with modifications and includes marketing activities among those that could generate innovation. Nanotechnology is inserted within the conceptual limits of innovation, featuring incremental innovation – when innovation aggregates some feature that is new and different from the existing product – and also revolutionary innovation – when a product, service, process, method or system that did not previously exist is introduced.

In Brazil, the prospect of innovation was enhanced in a recent text, under Law number 10,973 (known as the "Innovation Law") of December 2, 2004, which states: "innovation: introduction of novelty or improvement of a social or productive environment resulting in new products, processes or services" (art. 2, IV). It can be noted that its wording is very straightforward, and it is important to

11 Available at http://www.finep.gov.br/imprensa/sala_imprensa/manual_de_oslo.pdf Accessed on January 20, 2013.

12 Available at http://www.finep.gov.br/imprensa/sala_imprensa/manual_de_oslo.pdf Accessed on January 20, 2013, this definition is on p. 55 of the document.

highlight that this law was drafted before the publication of the third edition of the Oslo Manual. But Law number 11,196 of November 21, 2005, called the "Law of Goods", which establishes tax benefits for innovative companies, considers "technological innovation to be the design of a new product or manufacturing process, as well as the aggregation of new functionalities or characteristics to a product or process that involves incremental improvements and effective gains in quality or productivity, resulting in greater competitiveness in the market" (Art. 17, § 1). Brazilian Law absorbs international perspectives on innovation – especially the Frascati Manual and the OSLO Manual – internalizing them through ordinary laws, which fall within the national plan to stimulate innovation in the country.

Through Law number 13,196 of July 13, 2009, the state of Rio Grande do Sul established incentives for innovation and scientific and technological research, considering innovation to be the "introduction of new products, processes, services, marketing or organizational innovation, as well as improvement of the existing ones, in productive or social environments, aiming to expand company's competitiveness in local or global market and improve the living conditions of the society of Rio Grande do Sul" (art. 2, I).

The path that has been developed in this study so far flows especially into the concept of innovation adopted by the Rio Grande do Sul legislation, in which there is a clear concern for the improvement of "living conditions of the society of Rio Grande do Sul". This is the axiological perspective of Law and the openness for the appreciation of human beings and of environment. It is in this scenario that the triple helix formed by University, Industry and Government is projected. The choice was made to use "State" instead of "Government" because it is more comprehensive and enduring, under the inspiration of terms devised by Henry Etzkowitz (2009, p. 29, our translation).

Innovation, in this perspective, does not only consider products and processes, but knowledge generated in/by Universities, which interacts with the prospects for development of Industry and receives resources through public policies promoted by the State. The movement of the triple helix, which starts from a spiral, causes a true "capitalization of knowledge" and circulations on "macro and

micro levels": "macrocirculations move along the helix, while microcirculations occur within a single helix. The first level creates policies, projects and networks of collaboration, while the second consists of the power of individual helices "(Etzkowitz, 2009, p. 28-9, our translation).

An example of this movement of helices is the Competitiveness Forum on Nanotechnology, sponsored by the Ministry of Development, Industry and Trade[13], which is situated in a macrocirculation of helices, precisely because of its commitment to the formulation of public policies and of projects for regulatory frameworks on nanotechnology in Brazil. In addition, participation in microcirculations is also taking place, as Universities participate in this forum and attempt to find legal and juridical alternatives to enhance the transfer of knowledge through specific assistance for industries working with innovation in nanotechnology, taking advantage of the resources provided by State.

This circulation can be characterized as follows: "(...) Universities are the quintessential institution designed to promote lateral movement, through their educational function. (...) Recently, lateral movement has also occurred in the upper levels of universities, bringing together administrators and teachers with the skills obtained in other social spheres, and sending teachers into government and industry, with the necessary expertise in these institutions" (Etzkowitz, 2009, p. 29-30, our translation).

Although it is possible to see the chance of friction in the operation of the three helices given the proximity between the roles of each of the actors involved, this does not happen, because "this is the bright side of institutional cross-fertilization, through which each helix is infused with new ideas and perspectives of others, through the circulation of individuals" (Etzkowitz, 2009, p. 30, our translation). Therefore, the construction of innovation through federal and state legislation in conjunction with the Frascati Manual and the OSLO Manual, will occur via the triple helix.

Alongside these aspects, the proposed model aims to cope with the challenge launched by Eric Drexler, when he reports his perception of the technological

13 Available at: http://www.mdic.gov.br/pdp/index.php/politica/setores/nanotecnologia/80 Accessed on February 2, 2013.

evolution occurring in countries like India, China, Japan and Korea. He says: "(...) In part, the reason I am in Brazil today is to try to better understand the role that researchers in Brazil can play in this process worldwide. I hope it is a very important role, so that Brazil can also contribute and participate" (Drexler, 2009, p. 52, our translation). He shows that the movement of the triple helix that is the mainstay of innovation in Brazil still has to develop a great deal before Drexler's prediction can take place. The other countries mentioned above, especially China, Japan and Korea, have growing levels of research and innovation in nanotechnology. Important examples of this include Nanopolis Suzhou – The Nanotech Commercialization Hub in China and NNFC Nano National Nanofab Center and the research being carried out at KAIST – Korea Advanced Institute of Science and Technology. The latter two are located in Seoul, South Korea.

It is the construction of a model called a "knowledge-based economy", which means that it describes trends in economies that are more advanced in terms of greater dependence on knowledge, information and high levels of expertise, and the growing need for immediate access to these factors in the private and public sectors. Knowledge and technology have become increasingly complex, increasing the importance of interactions between firms and other organizations as a means of acquiring expertise[14].

For this, a number of different initiatives are necessary. These initiatives may enable the installation of innovation in an organization, whether academic, industrial, State, or at any level of government: innovation requires the use of new knowledge or a new use or combination of existing knowledge. New knowledge can be generated by an innovative company in the course of its activities (i.e. internal R&D) or externally acquired from various channels (for example, from the purchase of a new technology). The use of new knowledge, or the combination of existing knowledge, requires innovative efforts that can be distinguished from standard routines[15]. This article proposes the entry of another helix, representing Human Rights, creating a "quadruple helix" that ethically supports the movement

14 Available at http://www.finep.gov.br/imprensa/sala_imprensa/manual_de_oslo.pdf Accessed on February 2, 2013, this definition appears on p. 35 of the document.

15 Available at http://www.finep.gov.br/imprensa/sala_imprensa/manual_de_oslo.pdf Accessed on February 2, 2013, this definition is on p. 43 of the document.

of the other three helices, ensuring the necessary integration of innovation with a concern for humans and the environment. From this set of helices, there will be a new concept of innovation[16] and an effective autonomy for human beings. Their creativity will be ensured, setting the "right to know" in the following terms defined in the Declaration of Technological Rights of Workers of 1981: "new automation technologies, and the science on which they are based, are the product of a global accumulation of knowledge over several centuries. Therefore, workers and their communities have the right to participate in decisions and benefits related to these developments". (Soderberg, 2013, p. 31, our translation).This is the key point for the installation of the fourth helix, as it aims to bring this perspective with all living beings, the environment and the development of healthy conditions for a dignified life in community to the heart of nanotechnological innovation.

A case study that serves to illustrate the functioning of the movement designed for the four helices can be found in the Rio Grande do Sul legislation on innovation. Based on the definition of innovation contained in Law number 13,196/2009, Decree number 46781 was created on December 4, 2009, and established the PRO-INNNOVATION/RS program and regulated that law. Based on this definition, it is also possible to note that one of the fundamental guidelines of this program is underpinned by stimulus and support for innovative projects and companies that promote "care for the environment" in the state of Rio Grande do Sul. (art. 3, VI).

Another aspect that fits the movement of the "quadruple helix" is the part related to the aspects that will be taken into consideration for the design of incentives, among which we highlight, among other things, "the number of employees in a company who hold undergraduate, Master's and PhD degrees, the existence of approved projects in institutions that promote innovation, the execution of research and development activities – R&D, and the admission of specialized technical teams". (art. 6, II, III and IV).

16 This theme was the focus of a research Project entitled "As Nanotecnologias e o Direito: os Direitos Humanos como condição de possibilidade à regulamentação jurídica dentro de um cenário marcado pelo (novo) conceito de inovação"(Nanotechnology and Law: Human Rights as a condition of possibility for legal regulation within a scenario marked by the (new) concept of innovation) , developed in the scope of Edital MCT/CNPq N º 14/2010 - Universal / Edital MCT/CNPq 14/2010 – Universal, completed in November 2012.

"Appendix A" was later added to this decree, to provide guidelines for the submission of the Consultation-Letter, which is used to request the incentives mentioned in the PRO-INNOVATION/RS program. In this appendix, it is stated that one of the documents that must be attached to the consultation-letter is the preliminary environmental impact study, shown through the submission of the environmental license or environmental license application for the innovative project.

The range of issues examined shows that besides the interaction between University, Industry and State, the Innovation Law of Rio Grande do Sul upholds concerns with the ethical element typified by Human Rights and embodied by the interest in improving living conditions for the society of Rio Grande do Sul – this is the aforementioned issue concerning human beings – and also the concern with the environmental impact of the innovative project. Thus, the theory of "quadruple helix" is confirmed and demonstrated in a concrete situation.

The operation of each of the four helices highlights the need to break barriers and build bridges that are capable of "from different starting points, achieving the common goal of economic and social development based on knowledge". (Etzkowitz, 2009, p. 194-5, our translation). Each of the four helices must open up to the other in order to facilitate the flow of knowledge through each of them, creating the possibility for "capitalization of knowledge" from the emergence "of dynamics within knowledge production". This becomes practical through the "transformation of knowledge into capital, and the processes by which this occurs, such as intellectual property rights and patent systems, corporate research labs and consortia, technology transfers and partnerships, venture capital (public and private), incubators, etc." (Etzkowitz, 2009, p. 197-8, our translation). This is the movement that nanotechnology is causing and will certainly be the means to innovative development of the State of Rio Grande do Sul and of Brazil, in order to occupy the position Eric Drexler has planned for the country.

## CONCLUSION

Nanotechnology is transforming the relationship that humans have with the environment, because nanoscale allows for entrance into corners that were

previously hidden, reproduction and modification of existing and known natural and human creations. This Scientific Revolution needs to be properly sized, because the positive and negative results will be borne by human beings and the environment, where other living beings are located.

Studies of nanotoxicology are still incipient, but already indicate that there are risks that must be evaluated. Therefore, it is necessary to practice phronesis, ensuring prudent and careful analysis of the risks and opportunities of allowing access to nanoscale creations. The contributions of hermeneutics, generated by Martin Heidegger and Hans-Georg Gadamer, will be a creative and reasonable methodological way to operate the research and deliberation that this scientific moment demands. Therefore, nature must be regarded as "text" that through philosophical hermeneutics will receive meaning, showing that humans cannot survive without the environment. What is more, the environment is the condition of possibility for (finite) existence of human beings. That is to say: the environment does not belong to humans. Rather, it is the human being who depends on the environment. An example of concern of a Law concern with this form of installation of innovation is the innovation law of Rio Grande do Sul, which improved the system created by federal law: the Innovation Law and the Law of Goods.

Thus, knowledge capitalization, i.e. when knowledge comes to develop a key role in society, ensures decision-making that is favorable to human beings and the environment, through the use of practical reason, which must act within a certain time, taking certain a distance and waiting for ideas to mature. In this context, the "triple helix", designed by Henry Etzkowitz, which establishes a relationship between University, Industry and State in order to characterize innovation, receives one more helix, formed by the group of Human Rights. Human Rights are not considered mere theoretical guidelines for conduct and decisions, but a space for dialogue in which to converge the attention and respect for human beings and the environment. Therefore, there will be one helix that is concerned with the axiological issue in the construction of innovation.

The Innovation Law of the state of Rio Grande do Sul is a harmonic model that is able to provide visibility for the four helices: scientific innovation, which is

generated at Universities, is taken to be developed by Industry, through the bridge fostered by the participation of the State, recognized through tax benefits, since there is a concern for living beings within the ecologically balanced environment. These are the conditions that must be observed for the characterization of technological innovation.

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