Innovation and public understanding of science: possibility of new indicators for the analysis of public attitudes to science, technology and innovation

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INNOVATION AND PUBLIC UNDERSTANDING OF SCIENCE: POSSIBILITY OF NEW INDICATORS FOR THE ANALYSIS OF PUBLIC ATTITUDES TO SCIENCE, TECHNOLOGY AND INNOVATION [1]

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Abstract

In the context of a knowledge-based economy, in the last 50 years, countries and international organisms have systematized many indicators to evaluate inventive and innovative capacity, mainly related to science. But these indicators have almost exclusively focused on the supply side of invention and innovation, in which attention is given to people (entrepreneurs), organizations practicing research and development (R&D) and innovative companies and virtually none to the end users, like consumers or organizations not connected to R&D/innovation. Aiming at facing this insufficiency, this paper proposes new models to analyze innovation through indicators that show the relationship between the realms of science, technology and innovation and society as a whole. These sociocultural indicators represent the set of propensities to innovate in a given social group. Therefore, from the confluence of investigations in the field of Public Understanding of Science and Innovation Studies, five indicators of the propensity to innovate were chosen: efficiency, creativity, trust in science and technology, uncertainty tolerance and cooperation.

Keywords: innovation, science, society, Innovation Studies, Public Understanding of Science.

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1. Introduction

Despite the evident relevance of the theme of technological innovations, both for social and economic development, its studies were organized as an autonomous field of research at many European and North American universities only in the 1960s (FAGERBERG, 2005). Thus, in the last decades we have seen the consolidation of innovation studies – a field which aims at identifying and understanding how innovations emerge and diffuse, which factors influence them (including policies) and what its social and economic consequences are (FAGERBERG, 2013).

In this context of consolidation of a knowledge-based economy, in the last 50 years, countries and international organisms have systematized many indicators to evaluate inventive and innovative capacity, mainly related to science. At the same time, these institutions have been developing manuals to qualify and standardize research, such as the documents from the Organization for Economic Cooperation and Development (OECD), like the Frascati Manual, for the measurement of scientific and technical activities; the Oslo Manual for data collection on technological innovation; and the Canberra Manual, for the assessment of human resources in science and

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technology. However, these methodological manuals and so many others are, almost exclusively, focused on the supply side of invention and innovation, in which attention is given to organizations practicing research and development (R&D) and innovative companies and virtually none to the end users, like consumers, organizations not connected to R&D or innovation, or countries (GODIN, 2011, 2012).

Furthermore, analyses usually have not focused on the social and cultural implications of innovations in two senses. On the one hand, new technological products and productive processes can affect people's behavior, for instance, on consumer demand (product innovation), or on the relationship among workers in an industrial organization (process innovation). On the other hand, society's average behavior has important implications in the acceptance of innovations, mainly by consumers, and in the ability to create and improve products in specific territories (country, region, city, and so on).

Aiming at facing these insufficiencies, this paper proposes new models to analyze innovation through indicators that show the relationship between the realms of science, technology and innovation and society as a whole. These sociocultural indicators represent the set of propensities to innovate in a given social group.

First, this text shows the reciprocity between scientific activities and innovation activities. Later on some of the main challenges for the understanding of the innovation processes, mainly from selected approaches, will be discussed. Following that, the field of study public understanding of science is presented, with emphasis on its contribution to the development of indicators of innovation propensity. Finally, conclusions are drawn to wrap up the paper.

2. Importance of science for the innovation process

To start the discussion about the relationship between science and innovation, it should be noted that there is a conceptual difference between invention and innovation (FAGERBERG, 2005, 2013). While the first concept refers to the initial manifestation of a new product or process, the second is a first attempt to apply the former practically. In some cases, this differentiation is quite tenuous or even inexistent, like in nanotechnology and biotechnology, in which inventions are already born as innovations. In other words, both have novelty as a common characteristic, however, innovation differs from an invention in the usefulness which is sought for and which can take two forms: one as a practical application to society without commercial ends, and the other directly related with its commercialization.

A promising way of approaching this relationship – science-innovation – is to observe how innovation occurs, or just showing what is not to innovate. For that, it is necessary to observe the well-known, although partially mistaken, **linear model of innovation**. This model emerged in Vannevar Bush's report (1945), which described a proposal to organize the research system in the United States after the Second World War[11]. This representation proposes an underlying separation between basic research (science) and applied research (technology-innovation), in which the more one activity is in the field of basic research, the more it will be far from the applied field, and vice-versa. That idea was called static version of the linear model.

The dynamic version of the linear model supposes a one-way sequence, from basic research to the new artefact (or new technology), ready for its commercialization, therefore, representing an innovation. The succession would be, from the initial to the final points: basic research → applied research → development→ production and operations → *marketing*. This proposal presents two mistakes. According to Stokes (2005), the first concerns the difference between basic research and applied research, which would end up making these kinds of research conceptually distinct. The first kind would almost exclusively be interested in the fundamental understanding of the phenomena under study. The other would be concerned only with its practical use. Thus, the belief that understanding (basic research) and utilization (applied research) are conflicting, and necessarily separate, areas was being strengthened.

The second mistake indicates that that sequence with a definite order is wrong because it does not consider the diversity of possible relationships among their elements (KLINE; ROSENBERG, 1986; STOKES, 2005; FAGERBERG, 2005). Beyond the linear model, many ideas and contributions from productive activities laid the foundation for new scientific breakthroughs, as well as from the applied to the basic research. Actually, the linear model is just one of the many ways to innovate, instead of the only one.

[11] Actually, this report did not suggest the adoption of the linear model as the main alternative to promote innovations in the North American productive fabric. What happened was a simplification of Bush's proposal with the intention of communicating to the general public, in a captious manner, the relevance of the science policies. That communication was used by the North American scientific community spokespeople in the first Post-War years (STOKES, 2005).

A more appropriate articulation of the different kinds of research was proposed by Stokes (2005), known as the **quadrant model of scientific research** (Figure 1). It is based on experiences of the history of scientific and technological development, with each cell of the model matching some famous scientist or inventor, sometimes considering the fundamental understanding, other times practical use, or even a mix between understanding and utility. The upper-left quadrant, which considers only the pure understanding of the phenomena under study, is called **Bohr's quadrant**, after the Danish physicist Niels Bohr (1885-1962). Despite his exclusive interest in basic research in the field of quantum mechanics, Bohr's findings were fundamental, years later, for the development of advanced technologies.

Figure 1 – Quadrant model of scientific research (STOKES, 2005, p. 118).

Research is inspired by:		Considerations of use?	
		No	Yes
Quest for fundamental understanding?	Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
	No		Pure applied research (Edison)

On the other end, located on the lower right cell, there is pure applied research – **Edison's quadrant** (Figure 1). Here the focus is on the practical use of the findings, without any concerns about understanding phenomena in any scientific field. The quadrant is named after the inventor Thomas Alba Edison (1847-1931) who, despite his low formal instruction or theoretical knowledge, was responsible for the development of the electric light system and for more than 1000 patents.

In the upper right cell, called **Pasteur's quadrant**, there is use-inspired basic research, that is, that which is concerned both with the quest for fundamental understanding and the utility of inventions (Figure 1). The linear model did not consider the existence of this kind of research in this quadrant because it did not predict the possibility that a basic research would yield, at the same time, practical applications. This quadrant stresses the work of the French chemist and scientist Louis Pasteur (1822-1895), for his discoveries in the field of microbiology which, at the same time, contributed to public health; therefore, his research allied understanding and use.[12]

In the last quadrant, in the lower left position in Figure 1, there is the investigative work which does not seek to understand phenomena, nor any utilization which can be used to solve society's practical problems. Despite its emptiness, this quadrant would be filled with the research driven by the investigator's curiosity about specific facts. An example would be the birdwatcher's work by organizing a systematized collection of records.

The possible exchanges between the different quadrants of research are a noteworthy aspect (STOKES, 2005). Thus, there are innumerous cases of such exchanges, such as the activities in the fourth (empty) quadrant which gave rise to important contributions to Bohr's quadrant. Or research in Edison's quadrant (pure applied research) which served as a basis for unlikely and unexpected scientific breakthroughs in Bohr's quadrant, and vice-versa.

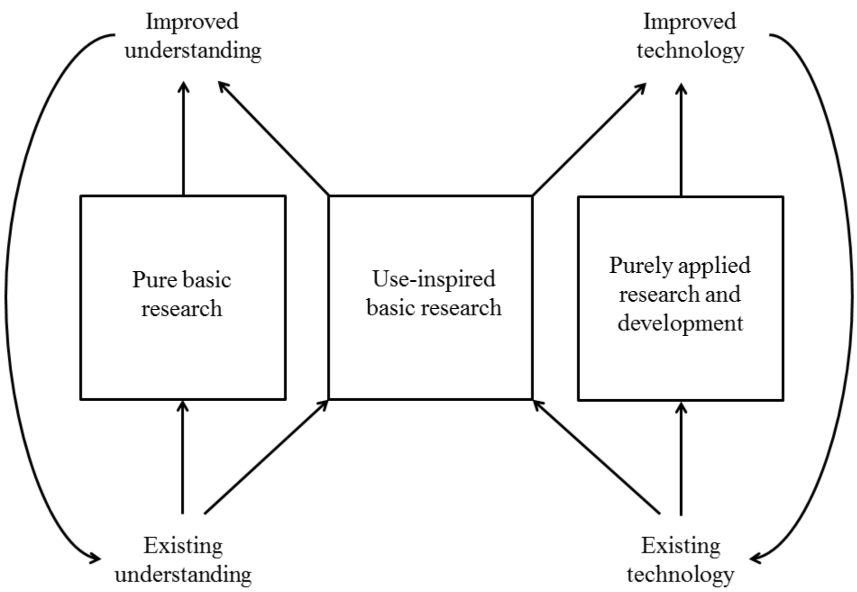
In Pasteur's quadrant, it is interesting to emphasize some attributes. Researchers belonging to it have an ability to clarify the social value of their studies to the general public (STOKES, 2005). Many times, their works are inspired partially on social needs, and, therefore, they create an important interaction between their scientific questions and the problems inflicting society. Moreover, this skill to combine social and scientific values in their practice makes these researchers ideal operators and planners in research funding systems with objectives related to society's needs. This situation evinces the incoherence of using resource allocation systems in research which separate social objectives from scientific objectives, which the linear model ends up dissociating erroneously.

From such considerations, it is possible to perceive the diversity of relationships among the different kinds of research in the quadrants model. Thus the **dynamic model**

[12] In this same quadrant, Stokes (2005) also pinpoints research in the field of social sciences, such as the ones carried out by John Maynard Keynes in the attempt to understand the economic dynamics in Macroeconomic Theory, as well as combatting economic depression; or in the birth of Modern Demography, by establishing the fundamental understanding of the origins of population change as a problem which demands organized public actions with solid scientific foundations.

of innovation stands out (Figure 2), devised by Stokes (2005), which better defines the ways in which many kinds of research foster new technologies or innovations.

Figure 2 – Revised dynamic model (STOKES, 2005, p. 138).



In this model it is possible to achieve any of its upper (improved understanding and technology) or lower ends (already existing understanding and technology) through many trajectories (Figure 2). For instance, an established knowledge can feed a pure basic research as well as a use-inspired basic research. In the first case, investigations can lead to new and better understandings of the phenomenon in question, which, in a later moment, will end up being recognized as an established knowledge (closing a cycle). In the second case, research with practical ends can generate a better understanding of the problem under study or a technological novelty. This new technology, when consolidated in society, has the possibility of supporting another investigation based on utilization, hence being able to produce, later on, another understanding, or a purely applied R&D activity to create new technologies.

Therefore, this model, by replacing the linear model (one-way from basic research to technological innovation), satisfactorily exposes the many upward trajectories as interactive and partially autonomous among them, some weaker (longer) than others (STOKES, 2005). On the one hand, science usually follows the way from an existing knowledge towards a more developed one through basic research, with a minimum participation of R&D (technological progress). On the other hand, technology often takes the route of innovations, passing through exclusively applied research (new projects, creative imitations, improvisations in the lab, etc.), in which scientific breakthroughs have little relevance. However, these poles – science and technology – establish, at specific moments, direct connections through use-inspired basic research.

3. New challenges for understanding the innovation processes

From the considerations on the quadrants model of scientific research and dynamic model of innovation, the need for an attitude of openness to new ideas and solutions becomes evident. This reflection is highlighted by Morgan (1997), by signalling two important weaknesses in the linear model. First, the lack of feedback from users and/or clients of innovations, in the realm of applied research (R&D), can generate problems in the satisfaction of the clientele in relation to these and future products. Second, there is an elitist view of knowledge, in which supposedly inferior forms of knowledge, for example, in the areas of engineering or production (know-how), are devalued in relation to properly scientific knowledge. Thus, the linear model is not effective in the current scenario of productive activities, at least in one important part of them. What is effective is the interaction in the realm of innovations, i.e., processes of interactive learning between firms and basic research, producers and users, firms and the social environment (TARTARUGA, 2014). Such processes are made easier or difficult, depending on the case, by values, conventions and habits (relational assets) specific to a region or nation.

This more comprehensive view of the innovation process, to a great extent, goes against the neo-Schumpeterian economic theory (SCHUMPETER, 1961, 1988).[13] Indeed, in the creative destruction of the innovative businessman, stage known as "Schumpeter Mark I", as well as in the creative accumulation of the big innovative company, stage named "Schumpeter Mark II", the neo-Schumpeterian approach analyzes the main innovation actors in isolation, searching for monopolistic advantages, which are usually ephemeral, ignoring innovation as a collective process and, therefore, dependent on its social and spatial contexts (MÉNDEZ, 1998, 2002; CARAVACA et al., 2002; GONZÁLEZ, 2006).

[13] Perspective that includes studies of innovation systems (EDQUIST, 2006).

However, the open view of innovation is presented in some of the main approaches to innovation studies, such as in the user-side view of innovation, in the open innovation, in triple helix and even in national/regional innovation systems. These approaches are described next.

The **user-side view of innovation** aims at studying the role of users as adopters of new products or services, not only as consumers of novelties, but also as citizens who are aware (or not) that their choices can have important impacts not only in the economic sphere, but in many others (social, political, environmental, and so on). Moreover, such approach considers the possibility of the user being also an active player in the creation of innovations. Thus, research from this perspective performs the following steps, some of them going against current research on innovation: to analyze final users and not only producers; to cover individuals, groups, organizations and the government; to measure different kinds of innovation (ideas, behaviors and things); to identify mechanisms to diffuse innovations; and to reveal the effects of innovations, for example, in quality of life, either good or bad (GODIN, 2011).

Another interesting approach is **open innovation** (CHESBROUGH, 2006a, 2006b), which has received significant attention in the academic and corporate environments in many countries. This kind of innovation is defined by the utilization of many sources of knowledge in and outside the company to improve their innovation processes. Knowledge outside the company often facilitates the introduction of its innovations in the markets. This way, useful knowledge flows can come from clients, suppliers, universities, laboratories, governments, other competing firms and other countries. Hence, in addition to generating knowledge, companies must be able to intermediate knowledge from the outside.

Nowadays, the idea of interaction between university, companies and government for the generation of innovations is championed as one of the most promising ways to promote socioeconomic development. The **triple helix** perspective exactly translates such interaction, emphasizing the interdependencies between these three entities, but also underlining the necessary independence of each of them (ETZKOWITZ, 2008, 2009).[14] However, even the advocates of triple helix

[14] It is worth remembering that the triple helix concept stemmed from the work developed by the Argentinian authors Sábato and Botana (1968), in the 1960s, when discussing the alternatives to overcome economic, scientific and technological delay in Latin America, in the concept known as "Sabato's Triangle".

(ETZKOWITZ, 2008, 2009) and others (CARAYANNIS; CAMPBELL, 2012) point to the necessity of adding a fourth helix, related to civil society[15].

All these approaches – user-side view, open innovation and triple helix – have as a common element some degree of cooperation to innovate among different economic and/or non-economic players. These cooperation processes can manifest through proximity between individuals or social groups. There are five types of proximity (BOSCHMA, 2005):

- **cognitive**, determined by the difference of knowledge accumulated by the players involved;
- **organizational**, which refers to the degree of control of productive or innovative activities in an organization or among a group of them, representing an organizational arrangement;
- **social**, which is based upon the social relations built every day among individuals;
- **institutional**, which emphasizes the sharing of social rules – institutions – that structure and give coherence to social interactions; and
- **geographic**, which is determined simply by the physical distance among potential innovation agents (individuals and companies).

The realization of an innovation process hardly happens satisfactorily without a combination of these five types of proximity among the players involved, which favors the exchange of knowledge and material conditions to innovate. Moreover, as the lack of proximity makes it difficult for innovation to happen, the excess of proximity also prevents it from happening. For instance, the lack of cognitive proximity (very different knowledge) very often causes misunderstanding between players and, therefore, makes the interaction difficult; notwithstanding, the excess of such proximity (very similar knowledge) between agents can lead to a situation of a lack of sources of new information.

In addition to the interactive learning processes, the ability to innovate also depends on the history of the places of social and productive organization in the environment in which the players develop their actions. According to Méndez (2002, p. 5):

[15] Carayannis and Campbell (2012) also indicate the necessity of a fifth helix: the environment.

> […] territories are the simple spatial projection of their strategies, however it is often ignored that they are a social construction, reflection of actions and multiple behaviors, accumulated over time, with the ability to influence also significantly the structure and workings of the companies themselves.

In certain cases, territory is no longer conceived as a simple object or stage and becomes a collective subject, because it has a system of players which animates it and can think and act on its behalf (MÉNDEZ, 2002; SANTOS, 2006). According to Méndez (2002), the lack of cooperation networks can be understood as a hurdle in the route to innovation and development.

Milton Santos (2006) insistently alerted that productive systems are increasingly a part of the technical-scientific-informational system. That is, it is on the basis of all forms of utilization of space, while taking part in the creation of new vital processes. Strategically to competitiveness, in contemporaneity, it has as its line of thought to add value with technological content in order to drive economic growth and generate more jobs.

Some authors/researchers who talk, in a way or another, about innovation in spatial contexts have in common the approach that innovation is characterized by complex processes which involve a plurality of players and institutions (CANO, 2005; COOKE, 2001; FERNÁNDEZ, 2001; FERRÃO, 2002; MOULAERT; NUSSBAUMER, 2005; LAZZERONI, 2004; RÜCKERT, 2004).

First, the theme of innovation in territorial contexts began to make sense from the decentralization of the territorial management resulting from the State Reform. Concomitant with the economic transformations from the crisis of Fordism, the national scale goes through transformations, widening powers to the local scales.

Second, it can be inferred that territorial innovation focuses on the uses of territory in relation to its form and function. In this regard, innovation is not restricted to just its technological facet, but it comprehends technological innovation, political innovation, economic innovation and social innovation. That is, it involves a systemic comprehension. Territorial innovation can be the object of analysis, but also a proposal for action pursuing strategic development.

The starting point for the construction of local environments which favor innovation or innovation ecosystems, especially when we devise actions which promote human development, is not the same for the different locations or regions. According to

Ferrão, in most situations local development cannot be left abandoned to its fate. That is, the invisible hand, either of the market or of civil society, has not spontaneously guaranteed the necessary conditions for development, in its various dimensions, to occur with the intensity and quality demanded by the most basic sense of social justice. Public action, either direct or indirect, thus, becomes indispensable (FERRÃO, 2002b).

New uses of territory can be devised and put into practice. However, it is worth remembering the argument by Moulaert and Nussbaumer (2005) when they say that innovation has searched for the instrumentalization of institutions for economic development, restructuration and improvements in competitiveness in regions and locations. Notwithstanding, prioritizing the economic dimension of innovation produces the false notion that business improvements consequently will bring social improvements, recalling the old story of "making the cake larger to share it later". The author claims that improvements in the non-economic dimension are still scarce in the debate and in proposals for territorial innovation. Beyond such reductionist (economistic) view, territory-based innovation needs to include a proposal to promote social innovation at a local level, including the satisfaction of basic human needs.

Here comes the question: how to promote territorial innovation seen as the creation of new economic and social uses of territory? Territory-based innovation does not come from heroic entrepreneurs, but from interactive learning coming from the cumulative knowledge process and the relations which are established among the different economic and social players within a national or regional space from a set of shared rules and procedures which allow the individuals to coordinate their actions to solve problems (FERNÁNDEZ, 2001).

According to Felix Ribeiro,

> […] innovation constitutes the result of multiple interactions among scientific, teaching, economic, political and institutional actors who, acting via a network, define an 'innovation ecosystem' based on the optimization of the complement competencies of these diverse actors and diversified cooperation scales (regional, national and international) (FÉLIX RIBEIRO, 2014, p. 103).

According to the United Nations Development Programme (UNDP), if well applied, technology can contribute to undermine social and spatial inequalities, improving people's quality of life.

Therefore, innovation is a cumulative and cooperative activity, which is dependent on historical trajectories (path dependence) and social and territorial contexts (TARTARUGA, 2014). An essential element linked to innovations, and common to all previous approaches, is their acceptance or practical receptivity by society (PINTO, 2005; QUINTANILLA, 2005; OLIVEIRA et al., 2009). Indeed, many technological novelties (based on science) did not have the expected, or at least immediate (when they ended up being used many years or decades later), social or economic impacts. In specific times and places, there can be social aspects (politics, economy, religion, culture, etc.) which prevent the use and the approval of really useful creations to society. In this regard, the general culture existing in a city, region or country has a strong influence on these choices, given its values, preferences, creeds, rules and conventions.

4. Public understanding of science (PUS): possibilities to study innovation

Most part of scientific production is carried out at universities or research centers. However, only a small fraction of the findings obtained and the discussions promoted is divulged to society, many times like products to be used, such as vaccines or new medical treatments. On the one hand, there has always been people’s curiosity about scientific knowledge. In addition to that, the public’s interest in science has increased as the presence of technology in our everyday lives has increased and, at the same time, the scientific events become an item on the news agenda with some regularity.

These findings are only connected to the most visible side of many broader questions about the relationship between science and society, which involves many different variables, and in which the array of topics to be discussed goes from the role of the media in the process to the importance of information about science in a democratic society.

To deal with these questions and get data to support the development of ways to understand these connections between science and society, a series of researches was organized around a common axis named Public Understanding of Science (PUS), which is described as “measures of science literacy, interest, attitudes, and public engagement with science" (BAUER; SHUKLA; ALLUM, 2012, p. 1). And these studies are carried out through

> [...] theoretical models and empirical studies based on quantitative and qualitative research methodologies, such as questionnaires and interviews, focus groups, media content analysis, study circles formed by citizens, among the main ones (LANDI, 2005, p.12-4).

Researches carried out in this realm, therefore, employ diverse instruments and methodologies which allow to describe and to analyze how the public and scientists are related. As Bauer and Jensen (2010) claim, PUS has two underlying objectives (one being scientific and the other political): on the one hand, to pursue the understanding that people have about science and, on the other hand, to mobilize scientists and other resources in order to promote the engagement of the general public with the scientific world. It is worth mentioning that studies carried out use large scale approaches, with emphasis on the measures of a given issue, as well as deeper approaches in which the investigation seeks for particular data of a given set.

The accumulation of obtained results with these two approaches allowed different theoretical models to come up in distinct moments. The first model is known as **science literacy**, and was widely present between the 1960s and the 1980s.

> The idea of scientific literacy sees science as an extension of the quest for reading, writing and numeracy. Furthermore, in a democracy, people make political decisions. However, the public voice can be effective only if citizens command relevant knowledge. [...]
> The idea of literacy attributes a knowledge deficit to the public. This deficit model of the public calls for increased efforts in science education (BAUER, 2009, p. 222-223).

In this model, science learning is seen as a skill to be developed by the individual, as a complement to other basic school activities. This proposition is justified by the fact that individuals must contribute to decision making in an enlightened way, i.e., driven by reasonable arguments grounded in scientific knowledge and not by motivations of another nature. This model is also known as deficit model (knowledge deficit), since it assumes that the public's knowledge of science is inferior than that of scientists and that a transference of some part of that knowledge is necessary through scientific education.

Although other models have been proposed later, there is a persistence of this standard, as evinced by the issue of May 2016 of the journal Public Understanding of

Science, which reveals the results of an essay competition whose main theme was the question: “Why does the ‘deficit model’ not go away?” (BAUER, 2016, p. 398).

The second model proposed is **public understanding**, which was prevalent during the 1985-1990. Many researchers (LANDI, 2005, BAUER, 2009, CASTELFRANCHI, 2013) consider as the landmark of this paradigm the publication of a report of the Royal Society of London in 1985. The main change introduced here is about the attitudes more than to the necessity of literacy and can be summarized by the maxim: “the more you know, the more you love it” (BAUER, 2009, p. 224). That is, the problem consisted of making people study science more and from this knowledge, they would adopt a positive attitude in issues related to the theme. Efforts have been made in that regard, however, the results obtained did not confirm changes in that direction.

Research carried out on the theme in Brazil shows that the initially established hypothesis did not hold valid. Castelfranchi (2013) analyzed the results obtained from national research on the theme, carried out in 1987, 2006 and 2010, and arrived at the following conclusion:

> Our most relevant result confirms a phenomenon already detected in other countries. The hypothesis that a higher levels of educational attainment or information would generally lead to more positive attitudes to the role of S&T in society is refuted by empirical data. There is a consistent group of people (around 60 per cent of Brazilians) who expresses a high interest in themes of S&T, but has a scarce knowledge of these themes of S&T and accesses a little scientific information. At least part of these people is ‘sincere’: they have a real interest in S&T (and also a general optimistic and positive posture), however interest and attitude are not associated with an active and concrete search for more information in the area (CASTELFRANCHI, 2013, p.1180).

The results obtained show that people are interested in science, regardless of their educational attainment. However, this result is not followed by an action to get more knowledge, but a certain sympathy, which can be understood as an optimistic view of science.

The third model discussed here, called **science-in-society**, was developed in the end of the 1990s and is persistent up to now. Its proposition occurred from society’s reaction to tragic events, such as the emergence of BSE (more popularly known as mad cow disease) and the debate about the introduction (or not) of genetically modified food. This proposition can be summarized as follows: “Science-in-Society reversed the deficit idea: not with the public, but with the scientific institutions and their actors who have lost the trust of the public" (BAUER, 2009, p. 225). In this paradigm, a deep change of viewpoint takes place, since scientists become to be questioned and evaluated according to distinct criteria in the academic environment. As a result of such approach, diverse initiatives from civil society came up to promote debates between scientists and the public.

The proposition of interpretive models from research was followed by the increase in the number of countries which started to make national and regional surveys. In the case of Latin America, the creation of a Latin American project that resulted in the construction of a Latin American indicator standard needs mentioning (LANDI, 2005, p. 12-9; VOGT, 2011).

Particularly in Brazil, research was carried out on the public perception of science by different institutions: national research organized by the Ministry of Science and Technology in 1987, 2006, 2010 and 2015; regional research carried out in the State of Sao Paulo by FAPESP (Sao Paulo Research Foundation) in 2001, 2004 and 2010; and in the State of Minas Gerais research carried out by FAPEMIG (Minas Gerais Research Foundation) in 2014. The questionnaires used in that research have a common basis of questions which allow for comparisons and also make it possible to add questions derived from bibliographic reviews and pilot testing.

5. A proposal of new science and innovation indicators: public attitudes to innovate

The proposal championed here presupposes the prominent influence of cultural factors in the processes of technological innovation. Based on this presupposition, the model of technical and technological culture is used (QUINTANILLA, 1998, 2005).[16] This model has as its main components, in the realm of any social group, (a) knowledge, creeds and representations (conceptual and symbolic) about techniques and technical systems – symbolic or representational component; (b) rules and conventions of behavior, skills and operational knowledge related to technical systems – practical or

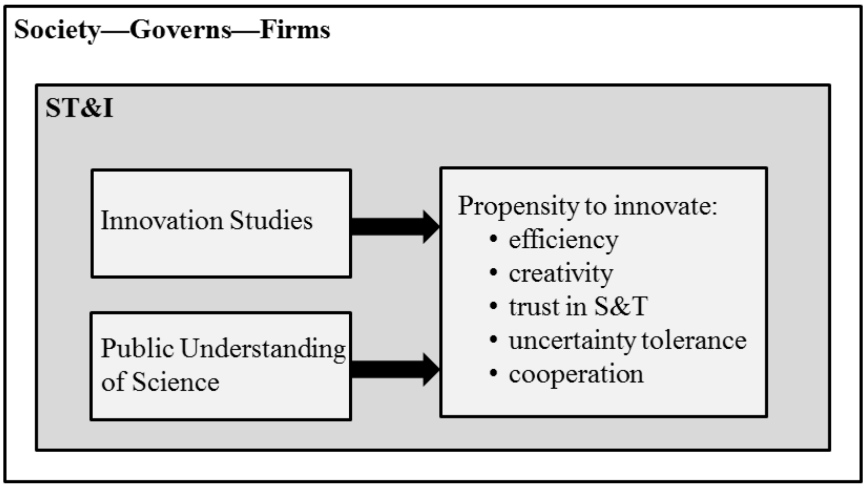
[16] It is important to highlight the difference between **technique** and **technology**, which is another presupposition in this work (QUINTANILLA, 1998, 2005). Whereas technique is basically the set of skills and knowledge which serves to solve practical problems of social groups, technology is any technique based on science, i.e., not only on the solution of problems, but also on the fundamental understanding of the phenomenon in question. Thus, a wider set of experiences and activities, not only from the scientific field, but also from traditional, indigenous communities, and other social groups, is considered.

operational component; (c) objectives, values and preferences related to design, acquisition, use, etc. of technical systems and knowledge – evaluative component.

The approach sustained here is evidently more intuitive than the more consolidated ones, like those in the field of innovation studies that quite often analyze the ability to innovate of a social group (mainly firms), which depends on the available technology. The intuitive approach emphasizes the propensity to innovate of an individual or social group, which, in its turn, depends on attitudes, representations and shared values (technical and/or technological culture) (QUINTANILLA, 2005).

Therefore, from the confluence of investigations in the field of Public Understanding of Science and Innovation Studies, mainly in the topics mentioned earlier, five indicators or dimensions of the propensity to innovate were chosen: efficiency, creativity, trust in science and technology, uncertainty tolerance (or uncertainty avoidance) and cooperation (Figure 3)[17]. These attitudes provide the recognition of the basic and fundamental propensities of an ordinary person having the interest, direct and indirect, and the ability to generate innovations, both technological and non-technological (organizational, social, etc.).

Figure 3 – Propensity to innovate and its environment.



Efficiency is characterized by the attitude of doing a job well or in the sense of evaluating an efficient action (minimizing the use of resources for a given objective or maximizing the results with a given resource, or both, doing more with less). Connected

[17] Exactly in the sense developed in this paper, the first four propensities were pointed out by Quintanilla (2005), whereas the last one, cooperation, by Tartaruga (2014).

to this propensity, some polemical issues can be observed, such as the inefficiency scandal or the waste of effort and resources. On the other hand, the search for efficiency causes a conflict with rituals, mainly those related to the regular and repetitive performance of actions or activities. Effectively, ritualistic performance plays a relevant role, in terms of mental and social health, by providing the individual with a certain degree of stability. Therefore, the construction of indicators for this dimension conducts the efficiency versus ritual discussion.

The valorization of **creativity** has a strong and evident relationship with the innovation process. The creation of novelties leads to another important confrontation: the new against the traditional. Thus, one seeks to find in social groups the tendency to think that the new is always better, without any concrete evidence, and even when evidence points to the contrary. The new is not ridiculous, a fad or a hype. In this context, attitudes of disrespect towards authority and tradition can emerge as well. However, one should pay attention to the aspects of tradition in a social grouping. As discussed in the earlier propensity, tradition is related to people's habits, which are equally structuring elements in the innovation and conviviality process. Indeed, tradition is not necessarily contrary to innovation. Some studies with experiences of innovation show that at many moments and places there have been cases of innovations that originated from past traditions which proved themselves very efficient later (EDGERTON, 2007). Furthermore, taking into account the conflict between change (new) and authority, there is an important discussion about social innovations as a powerful means of introducing transformations in society.

Trust in science and technology is seen as a means of solving practical problems and creating wealth and welfare. As previously discussed, the relationship between scientific knowledge and the creation of innovations plays a vital role in the realm of complex problems involving society, the economy, the environment, politics, etc.

Uncertainty tolerance, or acceptance of risks, is related to the entrepreneurial attitude, common to entrepreneurial individuals. This predisposition can be identified through the ambiguous feelings of anxiety caused by the possibility of a negative result (risk aversion) and the hope for a successful result (risk seeking).

Cooperation refers to the interaction dynamics which promotes cooperation networks between people and/or institutions, crucial constituent elements of innovation.

Mainly in the business scope, there is a mix of, presumably contradictory, cooperative and competitive behaviors. However, the most important aspects are connected to the diverse types of proximity that can define cooperation: cognitive, organizational, social, institutional and geographic.

The notion of open-mindedness acquires importance in this debate, for its intimate relationship with the propensities of creativity, uncertainty avoidance and cooperation. The open-minded attitude confronts with rigidity, dogmatism, lack of thought empathy (prejudice) and, in more extreme terms, conservatism and authoritarianism. Additionally, open-mindedness brings to light the concept, which is unavoidable in this discussion, of cognitive polyphasia, which is people's ability to acquire knowledge, concomitantly, through diverse sources (family, friends, work, science, religion, etc.). In other words, it refers to the human condition of registering specific knowledge from the coexistence of different modalities of knowledge in the same individual or social group (JOVCHELOVITCH, 2004).

Eventually, another aspect to be considered here is gender. All in all, in research about information access and social involvement about Science, Technology and Innovation, the analysis of questions presents relevant differentials in the answers, according to the interviewee's gender. In this regard, it is common that the results indicate that male respondents show a higher level of information and/or interest in these areas than female respondents. An example is the survey carried out in 2011 in Uruguay (ZUASNABAR, 2011) in which the proportion of men (22%) informed and interested (category of involved) in issues in science and technology represented the double of the correspondent proportion of women (only 11%) which answered affirmatively to that question.

This theme, which has been discussed in sociology of science and in gender and social inequality studies, has diverse branches to explain or elucidate the apparent differences in the attitudes of men and women regarding creative activity, innovation and scientific method.

According to Saboya (2013), following the classification proposed by Garcia and Sedeño, the issue of gender in the field of science and technology can be addressed through three kinds of approaches. The first one refers to the relatively lower participation of women in scientific careers and to the hurdles faced by them for their insertion. The second and third approaches, which are similar, have to do with the discussion of gender contents in the very definition of S&T, and with the masculine dominion in the construction of knowledge.

Taking the first approach, which is one of the most cited and commented in specific literature, it has been historically observed that women started to have a higher possibility of participation and visibility in the academic and scientific spheres only from 1960-1970, especially in more developed Western countries, and also in the former Soviet Union countries. One of the seminal texts covering these aspects is the paper "Women in Science: why so few?" (TOSI, 1975) by Alice Rossi, published in Science magazine in 1965.

The reasons for the higher or lower presence of women in scientific activities are related to factors which affect the set of working women, such as: (a): domestic support, translated as equal support from families to girls and boys in their school formation and in the continuity of their educational process in the adult phase; (b) more facilitated inclusion of women scientists at state universities and research centers, which, in relation to private organisms, demonstrate to be more accessible and less discriminating in relation to gender, race and other attributes; (c) existence of legislation, equipment and services providing protection to maternity, such as state kindergartens and early childhood schools.

As for the creative ability of women and their participation in the so-called hard sciences, a number of arguments have been used to relegate women researchers to secondary positions in scientific breakthroughs. As Tosi (1975) suggests, "man of science" is defined as a member of a community which shares a paradigm. By not recognizing women as their peers or disregarding their achievements, members of the male gender, who are the majority in some scientific communities, contribute to perpetuate the low participation of women in important fields of knowledge.

Likewise, traditional views of gender, which include the expectations of women's family obligations, continue to discriminate women in multiple manners, affecting equally researchers at the beginning of their careers and the others who have already a longer trajectory (SABOYA, 2013).

Thus, an investigation of this theme must be added to this research proposal, to verify to what extent the results featuring a low affinity of the female public in relation to S&T and Innovation are related to the concrete difficulties in being able to penetrate and take part in the process of new discoveries and in the construction of human knowledge. After all, as Tosi (1979, p. 71) underlines: “if women do not fully develop their intellectual potentialities and do not perform a creative task it is because the society in which they live does not expect them to do so”.

6. Conclusion

The proposal presented in this paper of analyzing the cultural aspects of general society as constituent elements of the innovation processes will probably find skepticism in some academic and business domains. Indeed, most studies approach the behavior of businessmen and firms, or scientists and universities/research centers, or the relationship among them. However, the proposition championed here does not discard nor devaluates the analysis of agents who are directly related to innovation activities. The cultural approach is here to complement those already consolidated studies.

In this same sense of complementarity, the proposal is grounded in the convergence and in the necessary dialogue between the innovation studies approaches and the ones of the public understanding of science (PUS), reinforcing a true interrelation between basic and applied research. A significant advantage coming from PUS is in the use of interview protocols, at regional and national scales. Additionally, the PUS surveys have already included in their current questionnaires one of the propensities to innovation, namely trust in S&T. Therefore, the novelty of this analytical proposal lies in the other types of propensities.

Finally, the set of propensities to innovate – efficiency, creativity, trust in S&T, uncertainty tolerance and cooperation –, unarguably represents an important factor to stimulate innovation processes in the realm of the economics of companies (market perspective) and the basic and applied science (academic perspective). And these inclinations, in both perspectives, are influenced by actions and behaviors of the society in which they are inserted.

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