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On the role of personal epistemology in the study of Science, Technology and Society

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ABSTRACT : The study of the social influence on the scientific praxis is an important branch of social sciences. This branch, however, has focused mostly on large scale phenomena or otherwise individual ethics. In this work we propose a way to approach this topic from individual psychological constructs using the cognitiveframe of personal epistemology. In particular, we show that the insertion of psychological variables to account for the self-control over personal epistemology is a useful tool facing the modern tendencies of the scientific work. The pertinence of this approach for a complete analysis of the science agents is discussed in several perspectives. We recall that, even when socio-scientific dynamics is not reducible to its constituents, it is precisely within the individuals that many important clues can be found to understend complex collective behaviors.

KEYWORDS : *Personal epistemology, interdisciplinary research, cognitive processes, social sciences*

I. INTRODUCTION

The interplay between science and technology is mediated by individuals and its social structures, which in turn are an expression of the specific context. As it is now extensively accepted [1], the processes of production, diffusion and application of the scientific knowledge cannot be explained without taking into account external variables such as economical motivations or political and military interests. With a particular strength since the last century, these processes link science to all other forms of human activity. In the following, with the aim of not to neglect the scientific objectivity in the discussion on the influence of social interests and conventions, we adhere to a two-dimensional operationalization of science: Science as activity and science as knowledge [2].

This classification is very useful for social researchers, even if its value is only theoretical and the limits between knowledge and activity is sometimes quite hard to determine. Within this frame, it is assumed that while science as knowledge is (and has to be) neutral, science as activity can be seen as an institution of the society an thereforeconstantly permeated and influenced by societal paradigms and structures [3]. In this approach the science as knowledge guarantees the cognitive value of theories and other expressions of knowledge, on the basis of intellectual honesty, understood as a commitment with objectivity. While the social environment is the place where contemporary scientific activity is performed, i.e. the science as activity, the science as knowledge is developed to a great extent within the scientists and other science agents. Therefore, the complete analysis of this topic has to include a complementary psychosocial study of the individuals.

In this work we start to build this path, by considering the epistemological beliefs system that individuals develop during her life, understood in the broad sense of what it is known today as personal epistemology. We argue that personal epistemology can be used as fundamental variable to unveil the puzzle of how social and scientific traits are braided within the subjects.

1.1 Theoretical basis

Here we subscribe to the classification of knowledge made by Karl Popper [4] distinguishing between the knowledge of common sense or ordinary, and the scientific knowledge. In Popper's epistemological position the scientific knowledge is considered as a development of ordinary knowledge. In this way science, philosophy and rational thinking emerges from common sense, even if the latter can be completely false in many situations. Unlike rationalists and empiricists, this approach do not intends to build a system with immovable grounds. The common sense is a basic knowledge to start from, a foundational knowledge that is in the basis of any rational discussion, but their beliefs can and must be questioned and criticized any time [5]. In this way there is a

continuity between ordinary and scientific knowledge, being the latter a result of the systematic application of rational critics on the former.

The psychological theories explaining the evolution of scientific concepts from childhood, establish that these concepts emerge separated from the so-called spontaneous concepts. This split occurs only at the early stage of the individuals life and are a result of the fact that its introduction comes from different social agents, e.g. the school in the case of scientific concepts and the family in the case of spontaneous concepts [6]. However, a very singular interaction is established between these concepts, so that when the child reaches a developed thinking that allows to operate with hypothesis as mental representations, the strong relationship between both types of concepts makes them difficult to isolate. In that point the abstract and generalist nature of the scientific concepts has developed the spontaneous concepts, and these in turn have been the foundational basis for the scientific concepts to be particularized, applied and operationalized.

From the point of view of the contemporary cognitive psychology, the individual evolution toward a scientific knowledge is mediated by a complex system of mental processes [7], including not only cognitive but also affective processes that are connected to the social context and experienced differently for different subjects. The current perspective is thus less rationalistic, considering the individuals as logically driven and capable of solving complex problems but at the same time failing to overcome many cognitive biases and emotional pitfalls that arise even in daily common tasks [8]. This is ultimately the result of its human nature and its social and cultural interactions through which the conception of reality was shaped and developed.

It is thus comprehensible that the epistemological beliefs will be marked by an idiosyncratic vision of the nature and the structure of knowledge, as a resemblance of the social, historical and cultural context. In turn, this construct integrates to the psychological formation that shapes the personality, intervening in the regulation of the behavior and influencing from inside both the individual practicing of science as activity and the individual comprehension of science as knowledge.

1.2 General Purpose

Two well defined directions can be drawn regarding the problem of establishing the complex interplay between science, technology and society through the psychosocial study of the individual subject as central element. The first one comprises the efforts that attempt to explore the individual as a conscious subject in its scientific activity. To this field belong for instance the studies of ethics, focused in the cultural influence and individual responsibility on the scientific praxis, as well as all other approaches to conceptualize and operationalize individual footprints of the science agents in science and society. But there is a second direction. That of the systematization of the ideas regarding the way in which the socio-historical context and the science itself influence the individual. This influence affects the conformation and development of a mental representation which is precisely the starting point to process the scientific information and deliver its conclusions in the scientific activity.

The utility of the studies on personal epistemology in the frame of the research on science, technology and society will be discussed in the following, contextualizing the influence of the social variables on the individual epistemological structures. The necessity of a new cognitive construct to operationalize the changes in the representation of the science as knowledge will be discussed as well.

II. THE BELIEFS SYSTEM

In its most simple formulation, the epistemological beliefs are the beliefs that an individual has regarding the nature of knowledge. This simplicity, however, hides out a discussion extended over decades on the correct conceptualization of the beliefs. Through these years the contribution of many researchers have built, from different perspectives and approaches, the conception of what we understand today as system of epistemological beliefs or personal epistemology.

The pioneer studies carried out by William Perry [9] focused on the effects that student's personological characteristics had on the multiple ways they interpreted the educative experiences. He found certain behavioral patterns that allowed to identify the type of meaning students were likely to give to her own experience. Moreover, it was shown that in the first years of university studies, perception and judging of knowledge was less developed that in the last senior years. It was concluded that the epistemological and ethical development is a qualitative reorganization of the formation of meanings through subsequent stages.

The epistemological development proposed by Perry was further studied by many authors. Some outstanding researchers defined their own terminology to refer to similar concepts and states according to their ways of modeling the process, e.g. the model of reflective judgment [10], epistemological reflexion [11] and argumentative reasoning [12]. New insights were advanced through concepts like ways of knowing [13], epistemological standards [14] and, eventually, epistemological beliefs [15]. The latter, while sometimes associated to the original specific model introduced by Schommer [15, 16], has became the most widely accepted terminology for the current scientific community. The concept of personal epistemology, on the other

hand, is representative of a more integrated vision of the many theoretical and methodological approaches for the same phenomenon, even if different authors use slightly different definitions.

For the purpose of this work the model studied by Schommer offers a suited theoretical frame for the analysis of the problematic. The model is called system of epistemological beliefs, and it transformed the comprehension of the personal epistemology construct in the early 90's by focusing in a multidimensional perspective. In this frame the personal epistemology is conceived as a system of multiple beliefs, more or less independents, whose complexity makes it impossible to be described in a general way as a single dimension. In order to determine the components of this system a type of instrument was designed to group main factors from simples answers to questions about the nature of knowledge and learning encompassing many possible visions.

The processing of the answers, typically by means of main component factorial analysis, delineates the individual characterization of the set of epistemological beliefs. Each belief is operationalized as a continuum component, ranging from the less developed or naive extreme, to the other where beliefs are more developed or sophisticated. The idea of the relative independence of the beliefs in the system is related to the asynchrony of the development. It means that a single individual can have at the same time naive and sophisticated beliefs both coexisting and shaping her personal epistemology. While in general dependent on the context, some particular beliefs have been found to be widely common and frequently identified across different cultural and academic environments. The original dimensions proposed in the Schommer's model [15] are listed below.

- Beliefs on the structure of knowledge: Simple and isolated knowledge vs complex and structured.
- Beliefs on the certainty or stability of knowledge: Certain, absolute and immovable knowledge vs tentative, contextual and improvable.
- Beliefs on the determinants of knowledge formation: Innate learning vs acquired and socio-culturally developed.
- Beliefs on the velocity of knowledge acquisition: Fast, all-or-nothing learning vs slow and systematic.
- Beliefs on the source of knowledge: Knowledge contained in authoritative authorities vs generated by observation and reasoning.

Beyond the detailed description of the structure of the epistemological beliefs, the contribution of the model includes an important characterization of the fundamentals of its development. Additionally, this has motivated a sustained trend of more specific researches to clearly establish the influence of particular belief dimensions on the learning process. These studies, mostly conducted in academic contexts, apply methodological tools that are based on large samples and allow further generalization [17, 18, 19].

2.1 Sophistication and scientific conception of reality

The studies on personal epistemology are mostly conducted within the fields of cognitive and educational psychology and use questionnaires and multidimensional analysis as well as interviews and other qualitative instruments. In both type of approaches the epistemological beliefs are evaluated in a scale, ordinal or not, ranging beliefs from naive to sophisticated. While dominant in the scientific literature, the basis of this evaluation has received several critics [20] and motivated improvements in specific subfields [21]. Nevertheless, it cannot be denied the fact that there are some preferential states of epistemological beliefs, that correspond to a better, more mature comprehension of the nature of knowledge.

In general terms the sophistication is understood within a clear scientific perspective. The type of epistemological positions that the studies in personal epistemology consider mature or sophisticated are those in higher agreement with the scientific method [22]. Thus, for instance, the belief in authority as the source of knowledge is less sophisticated than the belief in sources like observation and reasoning. This simplification is ultimately justified by the fact that the epistemological sophistication defined in this way has consistently shown high degrees of positive correlation with other meaningful variables such as study strategies, comprehension, interpretation and problem solving ability.

2.2 Development of the epistemological beliefs

While the exact nature of the development of the beliefs is hard to precise, the more accepted scenario is that personal epistemology starts to emerge since early in life. As the child interacts with different social groups like family, friends and school, this system of beliefs become more and more specific. It is plausible that in the subsequent stages of development the individual additionally form domain-general beliefs as the type of problems she faces become broader in nature [23]. The evolution of the beliefs system continues through the adult age, and involves a myriad of psycho-social variables. The role of education is shown to be instrumental.

Since the first studies on the development of beliefs along the educative process [9, 24], it has been demonstrated that formation and change of the beliefs are highly influenced by the level of instruction. A large number of works have focused in describing how this process takes place and which elements regulates it. Some authors claim that important conceptual changes takes place in the years of university undergrad. Many studies confirm this evolution in different cultural contexts.

Regarding curricular or occasional interventions to intentionally boost the development of the epistemological beliefs, a consensus has not been reached, as a clear and efficient method to achieve that goal has been elusive until now. This is indeed a consequence of the multiplicity of factors that underlies the formation of the beliefs, from idiosyncratic notions to emotions and vocationalpreferences, generating a strong resistance to possible changes. In the opinion of Schommer, the more rooted epistemological beliefs shape the perspective from which a mature person faces new unexplored fields of knowledge, and they could only change as a consequence of traumatic experiences or extreme challenges [16].

The way in which epistemological beliefs could be changed with intervention is a current open discussion in which the use of debate dialogs and design of intellectual challenges are the most outstanding candidates. This direction points toward the self awareness, so that individuals can make a conscious reflexion on their own epistemological beliefs. All these ideas are an important support to the proposal of this work and will come back in section 3.1 when introducing a novel construct: the meta-epistemology.

III. PERSONAL EPISTEMOLOGY AND TRANSDISCIPLINARITY

The expertise is a concept usually defined by looking at a number of traits and characteristics that distinguish between experts and novices in a domain of knowledge. It has been established that, in general terms, the experts solve problems by using more directed strategies, have a broader and structured knowledge, more motivation and deploy a better monitoring of their own development [25, 26, 27]. The influence of social and personal factors in reaching the expertise in certain domains has been studied and established, showing how family and social contexts can boost or hinder the efforts [28, 29].

This development, as we discussed before, should imply the concomitant formation of a personal epistemology at a mental level. In this way it make sense to associate the expertise with a particular mental structure, not only of knowledge and abilities but also sophistication in the comprehension of these knowledges and abilities.

On the other hand, the domain-specific nature of these abilities developed with the expertise is a well-studied and replicated fact. For example, the use of graphic representations in physics differentiate novices from experts, unlike what happens in biology [30]. In medicine, the expert develops certain particular narrative structures called illness scripts that are used to diagnose new cases [31]. In computational science the relevant characteristics of the experts include a high flexibility to use different syntaxes [32].

Since the 19th century the cognitive dynamics of science and its social organization have converged to the creation of an academic science composed of well-defined scientific disciplines. Each one of these disciplines having a particular development regarding the production, diffusion and legitimation of the scientific knowledge that became standard. Thus, the specific type of personal epistemology that the contemporary academy foster is strongly linked to the specific features of each domain of specialization.

The domain-specificity of epistemological beliefs [33, 17, 34] refers to the specialization or the field of application of certain group of beliefs. The relevant question in this topic is whether a particular belief is domain-general in the sense that it is applied to all areas of knowledge, or domain-specific, that is, valid only for certain well-defined areas. Let's now slightly modify this question and, instead of thinking in the specificity of a single belief, focus on the possible specificity of the whole personal epistemology.

As discussed before, each individual posses a set of epistemological beliefs forming a system that is called personal epistemology. For a single individual, these beliefs change when applied to different domains of knowledge, but always within her own personal scheme. However, it is expectable that individuals formed as experts in certain areas of knowledge will have relatively close personal epistemology in comparison with individuals that are experts in way different areas. Accepting the differentiation in the expression of this psychological construct for persons with different professional specialization is thus reasonable. It is a result of assuming that the individual epistemological beliefs tend to emulate the epistemological standards of the disciplines in which the individuals are expert.

Disciplines differentiate from each other to a large extent due to a number of epistemological standards like, e.g. the way of evaluate knowledge, the type of theoretical support that is considered strong, or the type of role that is played by the evidence. What is considered as a good theory or a good evidence is very different in psychology, chemistry or computational sciences; and, even if the scientific method is the mandatory schedule for all scientific activity, its general formulation allows an extremely large freedom in the epistemological sense. Consequently, each discipline performs the same method from its own epistemological platform, which has a marked socio-historical influence and whose most important footprint is that of determine the type of scientific questions that can be asked.

On the other hand, the science as activity has lately paid a special attention to multidisciplinary projects. Particularly since the last decades of 20th century, the intense development leaded by biotechnology and nanoscience, and recently followed by artificial intelligence, has redirected a large fraction of the scientific work to the conformation of teams with experts of very different areas, mostly within the applied research. This is a tendency that is going to still growing in the future, while at the same time does not mean a threat for the

vertical growth of the traditional disciplines. One of the main characteristics of the current times is precisely the increment of different ways of horizontal integrations as a necessary tool to generate new knowledge and technology [2]. Additionally, the science as knowledge has an own dynamics for the expansion of the limits of the knowledge. In this evolution, the limits of two disciplines eventually meet and new domains of knowledge emerge. The research in these new domains is called transdisciplinary and is not necessary linked to a need for particular applications, but rather is usually conceived as basic research.

3.1 The challenge of a meta-epitemology

From the poit of view of the epistemology, both the multidisciplinary and the transdisciplinary research have its own particular features. The multidisciplinary research attacks a problem from different disciplines, that is, by means of the work of experts with different epistemological perspectives. In turn, the transdisciplinary research develops in a rather new field of science which, even if located at the frontier of traditional disciplines, generate problems of its own singular nature, shaping a particular epistemological standard.

The study of personal epistemology in experts can play a determinant role to understand the context of the multidisciplinary activity. In this context the researchers must constantly recognize and, to some extent, understand the several views on the problem, which are much more than different tools and terminology. It is likely to think that a proper domain-specificity of the epistemological beliefs may be instrumental for the required attitude toward the multidisciplinary research. In that case the researcher will be allowed to easily think the problems across disciplines, beyond the elementary conjectures.

On the side of the transdisciplinary research, the scientist do not have to deal with different views of the problem, but rather to develop a new view and consequently create a new domain for her personal epistemology. Clearly the starting point will be the epistemological platforms of the nearest traditional disciplines, but the new set of beliefs cannot be a direct interpolation of them since the new context involves scientific problems and questions of a whole new nature. In such a situation, the capacity of develop a new domain with a new set of beliefs will be an individual ability, forged indirectly through her live and her scientific instruction.

We can thus define a new construct to study the individual monitoring of the evolution and expression of the epistemological beliefs. This construct will be of metacognitive nature since its central core is the self-regulation of the personal epistemology. We call it here metaepistemology, and it encompass all the conscious and intentional activities oriented to modify the own set of epistemological beliefs in order to better suit the new cognitive contexts.

The conceptualization and the study of the metaepistemology finds its utility and field not only as a mental element that express a purely psychological characteristics. As we have seen, the concept of metaepistemology emerges in a natural way in the study of the interplay between science, technology and society. It is conceived as a variable that can offer valuable information on the versatility and reach of the personal epistemological structures that allow an individual to perform contemporary scientific activity.

IV. CONCLUSIONS

The necessary knowledge and ability to undergo scientific research within the several scientific disciplines are in a great extent the product of a complex social interaction. Consequently, it is useful to develop studies of science, technology and society directed to the exploration of individual psychological variables. The cognitive psychology, in particular, has profiled for many decades the interest in the concept of personal epistemology. Here we have introduced this concept and discussed several features of it from a social perspective focusing in the contemporary scientific activity.

In this context, the construct of metaepistemology, a new contribution, is presented as naturally emerged from a psychological necessity in the description of the mental mechanisms involved in multi- and transdisciplinary research. Its basic characteristics is the description of the capacity of monitoring and self-regulating the process of organization of the own personal epistemology. In principle, a systematization of the metaepistemology can help to understand the horizontal movement of scientists and research groups; why for some scientists is more easy to engage in multidisciplinary projects while for others is a huge effort, and how are new disciplines conceived from different niches and schools.

Moreover, taking advantage from the current practical strength of the cognitive psychology, it would be possible to try to influence these elements at will, with e.g. curricular interventions. This perspective is of particular importance since, beyond the great theoretical and methodological advances in the studies on science, technology and society, the way to feedback this knowledge is by far the big absent in the literature. This work can serve as an introduction, motivation and guide for a more systematic and detailed study of this important topic of social sciences.

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