A METHODOLOGY FOR ETHNOSCIENCE:

THE NEED FOR ALTERNATIVE EPISTEMOLOGIES

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ABSTRACT

In this paper it is assumed a broad conceptualization of Science which allows for looking into common practices which are apparently unstructured forms of knowledge. This result from a concept of culture which is the result of an hierarchization of behavior. In this theoretical framework the concept of ethnoscience is analysed.

I.- Introductory remarks

In this paper we will discuss some basic issues which lead to some critical remarks on current methodologies for history, science and epistemology, and which may lay the ground for new approaches.

This relies primarily on developing the concept of ethnoscience.

Our subject lies on the borderline between History of Science and Cultural Anthropology. We may conceptualize ethnoscience as the study of scientific and, by extension, technological phenomena in direct relation to their social, economic and cultural background [1]. There has been much research on ethnoastronomy, ethnobotany, ethnochemistry and so on. Not much has been done in ethnomathematics, but some studies are under way. But ethnoscience, as a mode of thought, has not been recognized as a structured form of knowledge.

Much has been said about the universality of Science. This concept of universality seems to become harder to sustain as recent research, mainly carried on by anthropologists, show evidence of practices which are typically scientific such as observing, counting, ordering, sorting, measuring and weighing, which are carried on a more radical way than those which are commonly taught in the schools systems. This encouraged further studies on the evolution of scientific concepts and

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mathematical practices in a cultural and anthropological framework. We feel this has been done only to a very limited, and we might say timid, extent. A basic book by R.L. Wilder takes this approach and a recent comment on Wilder's approach by C. Smorinski [2] seem to be the most important attempts done by mathematicians. On the other hand, there is a reasonable amount of literature on this by anthropologists. The bridge between anthropologists and historians of culture and of science and mathematics is an important step towards recognizing different modes of thoughts which lead to different forms of science, which we may call ethnoscience.

Anton Dimitriu's extense History of Logic [3] briefly describes Indian and Chinese logics merely as background for his general historical study of the logics which originated from Greek thought. We know from other sources that the concept of "number one" is itself a quite different concept in the Nyâya-Vaišesika epistemolgy: "*number one is eternal in eternal substances, whereas two, etc., are always non-eternal*" and from this proceeds an Arithmetic [4, p. 119]. Practically, nothing is known about the logic underlying the Inca treatment of numbers which, by what is known through the study of the "quipus", represent a mixed qualitative-quantitative language [5]. And the concept of experience, or the experimental method, is something that may be discussed. When we follow the heavy argumentation of René Thom in favor of an Heracletian position and his challenge on what we might call the "experimental basis of scientific knowledge" in favor of theoretical reflexion, we have to admit the possibility of a new conceptualization for experience. See [15] for details.

These remarks invite us to look into the History of Science in a broader context, so to incorporate in it other possible forms of knowledge of natural phenomena. But we go further on these considerations in saying that this is more than a mere academic exercise, since its implications for pedagogy are clear, mainly if we refer to recent advances in cognition, which show how strongly are culture and cognition related. Although for a long time there have been indications of a close connection between cognitive mechanism and cultural environment, a reductionist tendency, which goes back to Descartes and to a certain extent has grown in parallel with the development of Science, tended to dominate education until recently, implying on culture-free cognition models. A recent holistic recognition of the interpenetration of Biology and culture opens up a fertile ground of research on culture and scientific cognition (see, for example, [6]). This has clear implications for Science and Mathematics Educations, as it has been amply discussed in [7] and [8].

II.- Some Historical Remarks on Methodology and Pedagogy

Let us look very briefly into some aspects of Science and Mathematics through History, mainly from the point of view of Education. We need some sort of periodization for this overview, which correspond, to a certain extent, to major turns in the socio-cultural composition of Western History. We disregard for this purpose other cultures and civilizations. For reasons which we shall not discuss in this paper, Mathematics appears universally as the earliest structured form of scientific knowledge. It has been recorded, in all civilizations, before other forms of scientific understanding of the world has been structured. For this, much of what follows will refer to Mathematics.

Up to Plato, our sources relie on his accounts and our reference is the beginning and growth of Mathematics in two clearly distinct branches: What we might call "scholarly" Mathematics, and which was incorporated in the ideal education of Greeks, and another one, which we may call "practical" Mathematical, reserved to manual workers mainly. Since the Egyptian origins of mathematical practices, there was a reserved space for "practical" behind it, which was taught to workers. This is carried on to Greek and Plato clearly distinguishes that "*all these studies* [ciphering and arithmetic, mensurations, relations of planetary orbits] *into their minute details is not for the masses but for a sellected few*" [9, Laws, 818] and "*We should induce those who are to share the highest functions of State to enter upon that study of calculation and take hold of it, (...) not for the purpose of buying and selling, as if they were preparing to be merchants or hucksters*" [9, Republic VII 525b]. This distinction between scholarly and practical mathematics, reserved for different social classes, is carried on to the Romans with the "trivium" and "quadrivium" and a practical training for laborers. In the middle ages we begin to see an approximation of both in one direction. That is, practical Mathematics begins to use some ideas of what is scholarly Mathematics in the field of Geometry. Practical Geometry is a subject in itself in the middle ages. The approximation of practical to theoretical Geometry is done after the translation from the Arabic of Euclid's Elements by Adelard of Bath, (early 12th century). Dominicus Gomdissalinus, in his classification of sciences, says that "*it would be disgraceful for someone to exercise any art and not know what it is, and what subject matter it has, and the other things that are premised of it*", as cited in [10, p. 8]. With respect to ciphering and counting, change start to take place with the introduction of Arabic numerals and the treatise of Fibonnaci [11, p. 481] is probably the first to make this mixing of practical and theoretical aspects of Arithmetic.

Next step in our periodization is the Rennaissance, where a new labor structure in the domain of architecture takes place with the appearance of technical drawing, which becomes accessible to brick layers, and the description of machinery, pictured thanks to the emergence of drawing. This allowed techniques to be reproduced by others than the inventors. In painting, schools became more efficient, and treatises began to be available. The approximation of scholars the general public is clear and scholars, who start to use vernacular for their scholarly works, sometimes write in a non technical language and in a style acessible to non-scholars. Best known as examples are Galileo and Newton, with his "Optik".

The approximation from practical Science and Mathematics to scholarly Science and Mathematics takes an increasing pace in the industrial era, not only for the reason of a necessity of dealing with increasingly complex machinery and instruction manuals, but also for social reasons. Exclusively scholarly training would not suffice for the children of an aristocracy which had to be prepared to keep its social and economical predominancy in a new order [11, p. 482]. The approximation of scholarly Science and Mathematics and practical Science and Mathematics begins to enter the school systems, if we may call education the pedagogical practices of these ages.

Finally, we reach a last step in this rough periodization by attaining the 20th Century and the wide spread concept of mass education. More urgently than in Plato, the question of *what* Science and Mathematics should be taught in mass educational systems is posed. It should be Science and Mathematics that keep the economic and social structure remanescent from the aristocracy when better training of subjects were essential for preparing the elites (as advocated by Plato) and at the same time allow this elite to assume effective management of the productive sector. In the case of Mathematics, this gave place to a "scholarly practical" Mathematics which we call from now on "academic mathematics", i.e., the mathematics which is taught and learned in the schools. In contraposition, we call *Ethnomathematics* the Mathematics which is practiced among identifiable cultural groups, such as national-tribal societies, labor groups, children of a certain age bracket, professional classes, and so on. This is equally true with Science in general. Much of the practices such as cure, plant growing and divination fit in the category of *Ethnoscience*, as contraposed to "academic science". This depends largely on focuses of interest, of motivation and on certain codes and jargons which do not belong to the realm of academic Science and Mathematics. We go even further in these concepts of ethnomathematics and ethnoscience to include much of the Mathematics and Physics which is currently practised by engineers, mainly calculus, which do not respond to the concept of rigor and formalism developed in academic courses. As an example, the Sylvanus Thompson approach to Calculus may better fit into this category of ethnomathematics. And masons and well diggers and shack raisers in slums are examples of practioners of ethnomathematics and ethnoscience.

Of course, this concept asks for a broader interpretation of what is Science and Mathematics. Now we include as Science and Mathematics, other than the Platonic ciphering and arithmetic, mensuration and relations of planetary orbits, also the capabilities of observing classifying, ordering, inferring and modelling. This is a very broad range of human activities, throughout history, which have been expropriated by the scholarly establishment, formalized and codified and incorporated into what we call academic Science and Mathematics. But which are alive in culturally identified groups and constitute routines in their daily practices.

III.- Ethnoscience in History and Pedagogy and their relations

We would like to insist on both the broad conceptualization of what is Science and which allows us to identify several practices which are essentially scientific in their nature. And also we presupose a broad concept of *ethno*, which includes groups which are culturally identified through their jargons, codes, symbols, myths and even specific ways of reasoning and inferring. Of course, this comes into a concept of culture which is the result of an hierarquization of behavior, from individual behavior through social behavior and leading to cultural behavior.

This relies on a model of individual behavior based on the cycle ... reality → individual → action → reality ... schematically described as

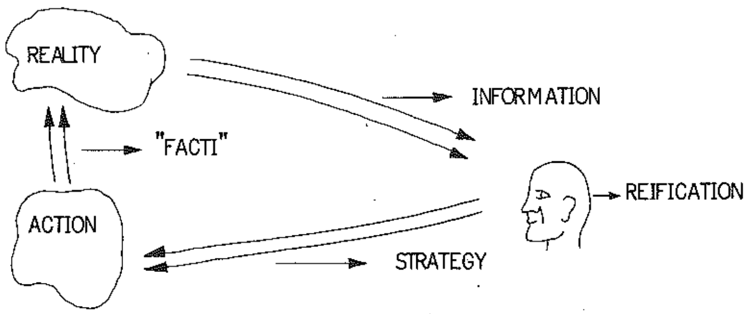

Fig. 1

In this holistic model we will not enter into discussion of what is reality, or what is the individual or what is action. We refer to [12]. We simply assume reality in a broad sense, both natural, material, social and psycho-emotional. Now we observe that the links are possible through mechanisms of *information*, including both sensorial and memory (genetic and acquired) systems, and which produce stimuli in the individual. Through a mechanism of *reification*, these stimuli give origin to strategies (based on codes and models), which generate action. Action impacts upon reality by introducing facti into this reality, both artifacts and "mentifacts". We have introduced this neologism to mean all the results of intellectual action which are not material, such as ideas, concepts, theories, reflexions and thoughts. These are added to reality in the broad sense mentioned above, and clearly modify it. The concept of reification has been used by the sociobiologists as "the mental activity in which hazily perceived and relatively intangible phenomena, such as complex arrays of objects or activities, are given a factitiously concrete form, simplified and labelled with words or other symbols" [13]. We assume this to be the basic mechanism through which strategies for action are defined. This action, be it through artifacts or through mentifacts, modifies reality, which in turn produces additional information which, through this reificative process, modifies or generates new strategies for action and so on. This ceaseless cycle is the basis for the theoretical framework upon which we base our ethnoscience concept.

Individual behavior in certain ways which are homogenized through mechanism such as education, build-up into societal behavior, which in turn generate what we call *culture*. Again an scheme such as the Figure 2, allows for the concept of culture as the strategy for societal action. Now, the mechanism of reification which is characteristic of individual behavior, is replaced by communication, while information, which impacts upon an individual, is replaced by History, which has its effects on society as a whole. We will not go deeper into this theoretical framework for the concept of culture. This will appear somewhere else.

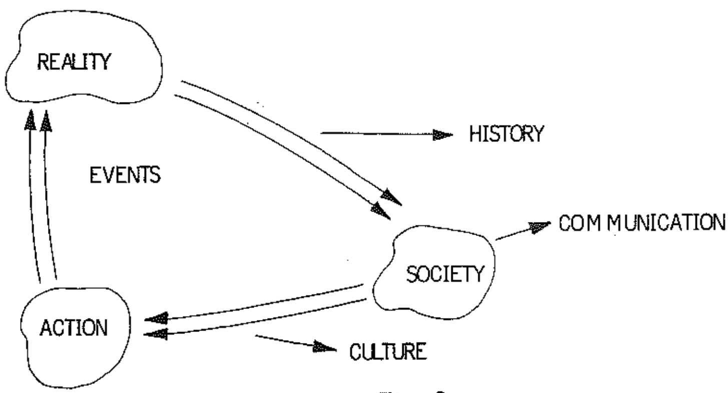

Fig. 2

As we have mentioned above, culture manifests itself through jargons, codes, myths, symbols, utopies and ways of reasoning and inferring. Associated with these we have practices such as ciphering and counting, measuring, observing, classifying, ordering, inferring, modelling, and so on, which constitute ethnomathematics and ethnoscience.

The basic question we are then posed is the following. How "theoretical" can ethoscience be? There has been long recognized that scientific practices, as those mentioned in the end of the previous paragraph, are known to several culturally differentiated groups, and when we say "known" we mean these are practised in a way which is substantially different from the Western or academic ways of doing them. This is commonly seen in the research of anthropologists and, even before ethnography has been recognized as a science, by travellers all over the world. The interest has been mainly as a curiosity or as a source of anthropological concern on learning about the way natives think. We go a step further in trying to find an underlying structure of inquiry into these *ad-hoc* practices.

In other terms, we have to pose the following questions:

1.- How to pass from "ad-hoc" practices and solution of problems to methods?

2.- How to pass from methods to theories?

3.- How to proceed from theories to invention?

It seems, through the study of History of Science, that these are the steps of the building-up of scientific theories. Research programs in the History of Science are essentially based on these three questions.

The main issue is then a methodological one, and it lies in the concept of History in itself, in particular of History of Science. We have to agree with the initial sentence in Bellone's excellent book on the second scientific revolution: "*There is a temptation hidden in the pages of the History of Science -the temptation to derive the birth and death of theories, the formalization and growth of concepts, from a scheme (either logical or philosophical) always valid and everywhere applicable (...) Instead of dealing with real problems, History would then become a learned review of edifying tales for the benefit of one philosophical school or another*" [14, p.1]. This permeates the analysis of popular practices such as ethnoscience and in particular ethnomathematics, depriving it of any history. As a consequence, it deprives it of the status of knowledge.

It is appropiate at this moment to make a few considerations of what is Science nowadays, regarded as a large scale professional activity. As we have already mentioned, it developed into this current situation only since early 19th century. Although scientists communicated among themselves and scientific periodicals, meetings and associations were known, the activities of the scientists did not receive reward as such. It came more as the result of patronage. Universities were little concerned about preparing scientists or training individuals for scientific work. Only in the 19th century to be a scientist started to be regarded as a professional activity. And out of this change, the differentiation of science into scientific field became almost unavoidable. The training of a scientist, now a professional with specific qualifications, was done in his subject, in universities or similar institutions, and mechanisms to qualify him for professional activity was developed. And standards of evaluation of credentials were developed. Knowledge, in particular scientific knowledge, was granted status which allowed to bestow upon individuals the required credentials for his professional activity. This same knowledge, practiced in many strata of society, at different levels of sophistication and depth, was expropriated by those who would have the responsability and power for professional accreditation.

We may cite as an example, taken in the case of Mathematics, of the parallel development of the scientific discipline outside the established and accepted model of the profession. The example is the discovery of Dirac's delta function, which only about 20 years after being in full use among physicists, was expropiated and became a Mathematical subject, structured in the Theory of Distributions. This is part of the internal dynamics of knowledge vis-â-vis of society.

There is unquestionably a timelag between the appearance of new ideas in Mathematics outside the circle of practicioners and the recognition of these ideas as "theorizable" into Mathematics, with the apropiate codes of the discipline, until the expropiation of the idea and its formalization as Mathematics. During this period of time the idea was put into use and practicioned. This is an example of what we call *ethnomathematics* in its broad sense. Eventually, it become Mathematics in the style or mode of thought recognized as such. In many cases, it never gets into this formalization, and the practice continues restricted to the culturally differentiated group which originated it. A mechanism of schooling replaces these practices by other equivalent practices which have been expropiated in its original form and returns in a codified version. The same is true for scientific knowledge in general.

We claim a status for those practices, ethnoscience, which did not as yet reach the level of science in the usual, traditional sense. Paraphrasing the terminology of T.S. Kuhn, which are not "normal science". Very unlikely it will generate a "revolutionary science" in the Kuhnian terminology. Ethnoscience will keep its life, evolve as a result of societal change, but the new forms will simply replace the former ones, which go into oblivion. The acumulative character of this form of knowledge can not be recognized, and its status as a scientific discipline becomes questionable. The internal revolutions in ethnoscience, which result from societal changes as a whole, are not sufficiently linked to "normal ethnoscience". The chain of historical development, which is the spine of a body of knowledge structured as a discipline, is not recognizable. Consequently, ethnoscience is not recognized as a structured body of knowledge, but rather as a set of "ad-hoc" practices.

It is the purpose of our research program to identify in ethnoscience a structured body of knowledge. For this, it is essential to follow steps 1. 2. and 3. above.

As it stands now, we are collecting examples and data on practices of culturally differentiated groups which are identifiable as scientific and mathematical practices, hence ethnoscience and ethnomathematics, and trying to link those practices as a pattern of reasoning, a model of thought. Both from cognitive theory and from cultural anthropology we hope to trace the origin of those practices. This way, a systematics organization of these practices into a body of knowledge may follow.

IV.- Conclusion

For effective research action in this field, it is required not only an intense experience in Science, but also investigative and research methods to absorb and understand ethnoscience. This clearly requires quite difficult anthropological research methods in the sciences, a field of study as yet poorly cultivated. Together with Social History of Science, which aims at understanding the mutual influence of socio--cultural, economic and political factors in the development of Science, Anthropological Science, if we may coin a name for this speciality, are topics which we understand as essential research themes not as an academic exercise in itself, as they are drawing interest now in some universities, but as the underlying ground upon which we can understand, in a relevant way, the evolution of scientific knowledge.

History of Science acquires also a more global, clearly holistic, approach, not only by the consideration of methods, objectives and contents of scientific knowledge in solidarity, but mainly by the incorporation of the results of anthropological findings into the 3-dimensional space which we may use to characterize this holistic approach. This is quite different than what has frequently and mistakenly being done, which is to analyse each of these components individually.

This has many implications for research priorities in the History of Science and has obviously a counterpart in the development of Science in itself. Clearly, the distinction of Science and Technology has to be interpreted in a different way. What has been labelled as Science, or we might emphasize pure science, and continues to be as such, is the natural result of the evolution of the discipline within a social, economical and cultural atmosphere, which cannot be disengaged of the main expectations of a certain historical moment. For example, in talking about Mathematics, it cannot be disregarded the fact L. Kroenecker ("God created the integers -the rest is the work of men"), K. Marx, Charles Darwin, were contemporaries. Pure Mathematics, as opposed to Mathematics, came into consideration at about that time, with obvious political and philosophical undertones. This distinction is highly artifical and ideologically dangerous. Clearly, to revise research priorities in such way as to incorporate national development priorities to scientific practices, which in the end generate university research, is a most difficult thing to do. This problem will lead naturally to a close of the theme of this paper. That is, the relation of Science and ideology.

Ideology is implicit in dressing, housing, titles and naturally in the forms of thought, including the inherent logic to structured knowledge. Of course, Science results from some logics which underlies the ideological roots of Western civilization.

We have assumed, throughout this paper, a broad conceptualization of Science, which allows for looking into common practices which are apparently unstructured forms of knowledge. This results from a concept of culture which is the result of hierarquization of behavior, from individual through social behavior and leading to cultural behavior. This depends on a model of individual behavior based on the ceaseless cycle ... reality → individual → action → reality ... The conceptualization of Science which derives from this model allows for the inclusion of what might be considered marginal practices of a scientific nature, and which we call ethnoscience. Of course, these common practices are impregnated of ideological overtones which are deeply rooted in the cultural texture of the group of practitioners.

It is the full understanding of these ideological overtones which lies in our research program of ethnoscience.

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