ETHNOMATHEMATICS, HISTORY OF MATHEMATICS AND THE BASIN METAPHOR

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1. Introduction.

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, such as health care, instrumentation, tools, artifacts in general, which are typically scientific, and methodological practices, such as observing, counting, ordering, sorting, measuring, and weighing, all performed in radically distinctive ways in different cultural environments. This has encouraged further studies on the evolution of scientific concepts and practices within a cultural and anthropological framework. We feel this has been done only to a very limited, and we might say very timid, extent.

On the other hand, there is a reasonable amount of literature on this by anthropologists and psychologists. To relate these researches with the work of historians and philosophers of Science and Mathematics is an important step towards a broader understanding of Science and Mathematics and their places in modern society. This has been the essence of my work in the Programme Ethnomathematics[1]. I feel this is an important step towards recognizing different modes of thought which lead to different forms of science, which we may call Ethnosciences.

There has been much research on ethnoastronomy, ethnobotany, ethnochemistry and so on. Particulariy, ethnomethodology is of growing importance in general sociology.[2] Researchers in this field rely on ethnography, conceptualized as the use of direct observation and extended field research producing a naturalistic description of peoples and their culture, uncovering codes, symbols and categories of analyses which these peoples use to conceptualize, to explain, to understand, to interpret reality. Obviously these intellectual instruments, codes, symbols and categories of analysis, derive from the natural and cultural environment within the reach of individuals and peoples. The generation of these instruments is the essence of studies in cognition and culture.[3]

Although there is an implicit contradiction when we talk about ethno-disciplines, research conducted by specialists in the current academic disciplines tend to transfer the disciplinary reduccionism to the ethnomethodologies. By positioning ourselves in a multidisciplinarian, interdisciplinarian and transdisciplinarian dimension, that is, in a holistic perspective, we may overcome these contradictions. We are thus lead to regard ethnoscience in a much broader way, avoiding the reductionist distinction of chemical, physical and biological phenomena, and other dychotomies such as C.P. Snow's two cultures and rejecting the view that mind and body as distinct, even autonomous, entities. These two forms of reductionism have been disastrous in looking into the History of Science. Particularly serious is the situation of Mathematics, whose

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[1] I use wording Programme in a sense closer to I. Lakatos. It is a clear recognition of the dynamical characteristics of knowledge: from ist generation it goes through organization , both intellectual and social, and through its diffusion. Although each of these aspects is studied in a discipline, respectively cognition, epistemology, history, politics and education, it is practically impossible ti understand and explain knowledge in such a fragmented way.Our use of the word "programme" reveals a holistic approach.

[2] Wes Sharrock and Bob Anderson *The Ethnomethodologists* Ellis Horwood Limited, Chichester, 1986 gives an introduction to this new research area.

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essence is lost in the reductionist context. The epystemologies of mathematics which are bound to the reductionist paradigm are obviously distorted - unless one regards mathematics as culture free, which is the most current view. These major distortions are transfered to the History of Mathematics. Ethnoscience allows us to avoid these distortions. We use the term Ethnomathematics as the intellectual constructs that precedes and organize those considered in science. We will now explain the fundamentals of this terminology.

2. The Programme Ethnomathematics

These remarks invite us to look into the History of Science in a broader context, so as to incorporate other possible forms of knowledge of natural phenomena. But we go further on these considerations by saying that this is more than a mere academic exercise, since its implications for a redeeming pedagogy are obvious. To justify this assertion we appeal to the recent advances in cognitive science, which show how strongly culture and cognition are related. Although for a long time there have been indications of a close connection between cognitive mechanisms and cultural environments, the reductionist tendency, which goes back to Descartes and to a certain extent has grown in parallel to the development of Science, tended to dominate education until recently, implying culture-free cognitive theories. This is the essential criticism to piagetian approaches to both education and history.

Let us look briefly into some aspects of Science through history, mainly from the point of view of its transmission and institutionalization. We need some sort of periodization for this overview, which corresponds, to a great extent, to major turns in the socio-cultural composition of Western History. It would be very difficult for us to get started with a periodization based in the history of other civilizations, although we grant all the biases resulting from this. Mathematical ideas, understood as practices and reflexions which deal with quantity and quality. Measurement, counting, inferring, ordering, classifying, spatial configuration and other similar behaviors appear universally as the earliest structured forms of knowledge. These were recorded in every civilization before other forms of knowledge. "The category 'mathematics' is Western and is not found as such elsewhere. That is not to say that mathematical ideas [as those mentioned above] do not exist; it is rather that others do not distinguish them in the same way"[4] . On the other hand, in the language of J.F. Montucla, mathematics appears as the essential first manifestation of knowledge, even preceeding philosophy. Indeed, to explain, to understand, to cope with reality, for which we use the Greek root *mathema*, has been, since the early ages of our species, the first manifestation of intellectually organized knowledge, transmitted from generation to generation. In the process of acquiring this knowledge, it was structured and organized according to the cultural, and obviously the natural environment, thus generating different ways, different styles, different modes, different techniques (one may use the root *techné*, that is, different *technés*) of explaining, of understanding, of coping with reality. We refer to this as the elaboration of different *tics* of *mathema*. The socio-cultural and natural environmental dependence for these developments is expressed by the prefix *ethno*. Thus when we see knowledge as part of the evolution of mankind we refer to *the generation of tics of mathema according to different ethnos*. We have thus coined the term ethno mathema tics. This obviously includes but is not restricted to the concept of mathematical knowledge referred to by J.F. Montucla. This is true not only in Greek civilization, but in every culture. Of course, the development of different modes of thought gave way to different disciplines as these modes of thought became known. So when talking about knowledge identified as Science, as Philosophy, as Art, as Religion, we are indeed looking into distinct forms of explanation, of understanding, of coping with reality.

This is ethnomathematics. The Programme Ethnomathematics looks into the generation, the intellectual and social organization and the diffusion of forms of explanation, of understanding, of coping with reality in different socio-cultural and natural environments. Of course, a

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[4] See the chapter by Marcia Ascher and Robert Ascher : 12.1 Ethnomathematics in *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, 2 volumes, ed. I. Grattan-Guinness, Routledge, London, 1994, pp. 1545-1554; p. 1545.

comparative study is absolutely natural. When looking into the History of Mathematics, now referring to the discipline recognized as such by standards that were set after the XVII and XVIII centuries, we recognize the Programme Ethnomathematics as germane.

The Program Ethnomathematics must be interpreted in the broad sense of scientific knowledge in general. Indeed when coining the word ethnomathematics I indulged in an "abus d'étymologie". A similar need was felt by Master Bourbaki fifty years ago! Indeed "ethno" stands for culture or cultural roots, but we extended it to natural environments, obviously closely related. "Mathema" is the Greek root for learning, understanding, hence explaining, and we extended it to include, which is obviously closely related to, dealing and coping with reality, and "tics" is a modified form of techné, which in in the root of the words arts, techniques, which are onviously different modes of thought. Thus "ethnomathematics" stands for distinct modes of explaining and coping with reality in different cultural and environmental settings. This is a broad theory of knowledge, in which we recognize, as said in the beginning, that codes of measurement, counting, inferring, ordering, classifying, spatial configuration are the earliest manifestations, both in the development of children and in the intellectual development of mankind. It is absolutely natural to identify sources of knowledge with the *mathema*. Obviously, not with the different tics developed in distinct *ethnos*.

Although the idea of examining the strong links of Science and Mathematics with the socio-cultural and natural environment has been going on for some time, these links have always been faced as less fundamental than the inner organization of theories themselves. Formal logics has reached the status of rationalitypar excellence. Science and Mathematics rely on logics and have been considered as context-free. Some timid exceptions are seen mainly in a few elementary curricula. Ethnomathematics covers all the practices of scientific and mathematical nature, such as sorting, classifying, counting, measuring, which are performed differently in different cultural settings, through the use of practices acquired, developed and transmitted through generations. Of course, reasoning, inferences and forms of logics are thus noticed.[5] An important contribution to ethnomathematics comes from the work of anthropologists since the beginning of the century and more recently of psychologists and sociologists, who have recognized different ways of counting and measuring, even of classifying and of inferring, in distinct native cultures all over the world.

It is possible that the term ethnomathematics was used before, by some reseracher, although I have not seen it before. Ethnobotany, ethnopsychiatry, ethnomethodology and several others of a similar nature have been in use for some time, in most cases referring to the respective practices of native populations. Some scholars see ethnomathematics restricted to this sense. Although this narrow sense is not excluded from our program, our concept of ethnomathematics is much broader, as I have explained above.

The steps from the generation through the progress of knowledge, in particular of mathematical knowledge, is the result of a complex conjunction of factors. Among them we recognize practices resulting from immediate need, relations with other practices and critical reflexion, hence theorization over those practices, curiosity and some sort of intrinsic cultural interest. Thus, the Programme Ethnomathematics calls not only for a broader view of Mathematics, embracing practices and methods related to a variety of cultural environments and normally left aside, but also a more comprehensive, contextualized perception of the processes of generating, organizing, trasmitting and disseminating mathematics throughout the History of Mankind.

There have not been doubts that the factors mentioned above in the generation of mathematical ideas produce ad-hoc knowledge. The main question is to realize when ad-hoc knowledge passes to methods and theories and from theories how does one proceed to invention. These questions are germane to any investigation of the nature of knowledge, both from the historical and the epistemological viewpoint.

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In the specific case of mathematics, these questions give rise to challenging questions:

i) where do mathematical ideas come from;
ii) how are them organized;
iii) how does mathematical knowledge advance;
iv) do these ideas have anything to do with the broad environment, both socio-cultural and natural;
v) what is the time span between advances in mathematics and their incorporation in the educational process?

To understand the Programme Ethnomathematics, it is first of all necessary to accept the fact that Mathematics is a construct of human mind. It is knowledge generated by human beings, organized in a certain intellectual framework which is recognized by its practitioners as Mathematics. Let us not attempt to define Mathematics. The breadth of the domain of Mathematics is seen in the Subject Classification of MR/ZM, as well in the recent published Volume II of the American Mathematical Society Centennial Publications *Mathematics into the Twenty-first Century*. Although some scholars trace the History of Mathematics back to Classic[5] Antiquity, the characteristics of current Mathematics are easier to recognize after the 17th Century.

In general, it is practically impossible to isolate Mathematics - and indeed any other form of knowledge - from others disciplines in the historical period longer than 400 years ago. How can one fail to relate the Olympic Games with the naissance of Greek Mathematics? Or the religious rituals of the Xingu tribes in Brazil with the development of their Sacred Geometry? The cost of a reductionist look into history, normally the result of epistemological biases, is a narrow and distorted vision of history. To look into history as the overcome of epistemological obstacles is an example of such a narrow approach. Epistemological "regards" into the past are biased views of history. Much of the appeal to a Greek heritage may lead to extremes. It is not inappropriate to recall a comment by Peter Calvocoressi when he refers to a German speaking community in India about a thousand years ago: "Similar surmises supposed the Trojans to be Germans who had got to Troy in some Germanic *Völkerwanderung*"[6]. This leads to a false impression, conveyed through traditional historians and philosophers of Mathematics, of a continuity of Greek Mathematics into Modern Mathematics. This is much of what we might call the "umbilical" view of the History and Philosophy of Mathematics. The contributions of European medieval thought, particularly during the build up of Christianity, to Modern Mathematics (understood as the Mathematics springing out of Descartes, Newton and contemporaries) can not be ignored. But it is difficult to isolate and sometimes even to recognize Mathematics as the result of the cultural efervescence of a certain period. This is exemplified by the study of knowledge in the Middle Ages in various distinct cultural traditions. Looking into the Roman times and to other cultures of the period, there are many practices, modes of thought and theories which have many characteristics of what we now label Mathematics but which would not be called Mathematics nowadays. This is also seen in many manifestations of Greek and Islamic intellectual production.[7] Our construction of History, about 1,500 years later and with all the identifiable biases, sometimes gets closer to Science fiction[8].

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6 Peter Calvocoressi "A whorl on a stone" *Times Literary* Supplement N° 4785 (12/16/94), p. 32.

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8 Historians of Mathematics probably would benefit more in looking closer into the Philosophy of History than the Philosophy of Mathematics. It is clear that, the same as Logics, Philosophy of Mathematics and Epistemology in general are part of current thought, in particular of current ideology, hence are chapters of the accepted Mathematics nowadays. They are obviously disciplines subbordinated to History. To look into thesedisciplines with current views causes several distortions, since obviously current History will influence the subeordinated disciplines. See the beautiful essay of Bernard Lewis *History Remembered, Recovered, Invented* Princeton University Press, Princeton, 1975.

3. Human Behavior and the Generation of Knowledge

Generation of knowledge is a permanent activity of human beings. It goes on and on in different environmental settings, according to needs, curiosity and other forms of stimuli. Among the several stimuli we have to consider cultural encounters and mutual exposition of different modes of thought. This has been well studied by Gregory Bateson.[9] In the evolution of cultural forms subjected to mutual exposition, the possibilities are first an absolute domination of one form, either leaving the others in the state of latency or eventually, the total elimination; second, allowing co-evolution, which eventually leads to new cultural forms. This second possibility occur in systems which are tolerant of the different, of the stranger. A well known example is early Islam. In this case the evolution has a strong participation of popular strata of society. Regretably, much of this escapes the analysis of academic history. An important trend in the historiography of the late 400 years, represented mainly by George Rudé, E. J. Hobsbaum, Christopher Hill, looks into "history from below".[10] This is particularly important in the History of Mathematics in medieval times and early renaissance.

There has recognition of the role of Islam in transmitting Greek Mathematics and now there is a growing trend in historiography to recognize original contributions of Islam and the contribution of African, Indian and Chinese cultures during the Eastern middle ages. These facts have been downgraded in the traditional historiography of Mathematics, which by and large originated from the imperial European historiography of XVIII and XIX centuries. It is unsustainable the argument, still prevailing, that there might have been some mathematical activities in the peripherical nations in the past, but that those were activities of an ad-hoc nature, not structured as formal knowledge [11] . Thus the consideration of its history does not belong to the History of [World] Mathematics. At best one would say that it does not belong to the History of European Mathematics, as one might argue that European Mathematics does not belong to the History of [World] Mathematics. The character of the universality of Mathematics is historically unsustainable. Universality in the History of Ideas is a fabrication of the colonial ideology.

A new historiography reestablishing authentic universality is needed. There is much agreement about this in several areas of knowledge, but the History of Mathematics seems to be regarded as immune to this movement. Indeed, the tone of some reviews and referee reports on recent books and papers on the History of Mathematics focusing on this sort of redeeming cultural history or a non-eurocentric view, is discouraging and sometimes contemptuous. The quote "No one would dare to propose now, as did some scholars in the middle of this century, that there might be an African past, but that for the lack of writing its history did not exist"[12] expresses what I mean. Indeed, categories which were introduced in the last two or three centuries are used to disqualify historicity exactly in the same vein as the use of writing, as in this quote. Obviously, African applies to any peripherical nation and writing can be understood as any form of register and codified knowledge. These are not clearly recognized in many cases. Recent scholarship in pre-columbian cultures illustrate this. Mayan books were used as exotic "wall paper" in XIX century Germany.[13] This is also clear when we notice that the first non religious book published in the New World was a treatise dealing with the arithmetic of the

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Aztecs, in 1557[14] Less than a century later, this book had lost its interest and underwent a complete oblivion, and with it pre-columbian arithmetic. It was replaced by the arithmetic of the Spaniards. Of course, the suppression of the history of a people implies the removal of all traces of structured knowledge, labelling all forms of knowledge as ad-hoc, easily and contemptuously labelled "popular wisdom", superstition and folklore.

The multiplicity of cultural factors that are regarded as essential in the definition of human behavior can not exclude the modes of explanation, of understanding, of coping with reality, and this means "ethnomathematics". This is essentially the dynamic process of the production of new forms of thought, of more sophisticated expressions of the ingenuity of individuals and societies in satisfying their needs of survival and of transcendence. This is the obvious result of the process of cultural dynamics.

Distortions in this process was and continues to be done in the name of a god, of customs and morals, of "civilization", of democracy - in lieu of of submission to the King! - of "better health", of modernity, of progress, of stable economy, of sustainability, of higher productivity, and so on. We find the rethorics of conquest or of the civilizatory process, of which the previous examples illustrate strategies based in Mathematics, practically unchanged in its essence since the XVI century. Some may be asking: "But what does this have to do with ethnomathematics?". I invite those who do not see the connection to give a new look into recent theories of cognition and history.[15]

4. The Basin Metaphor and a Sociology of Mathematics

There is no way to deny that [Western] Mathematics is essential in the modern world. Public opinion is ready to support investment in mathematical research in spite of being absolutalety unable to guess what kind of research is being supported, professionally succesful parents invest in the mathematical education of their children and even accept that a child does an entire year again if he/she fails in the final exam - in spite of him/her, succesful parent, declaring that while they were in school and up to nowadays never understood mathematics. "Miraculously" they graduated in spite of successive failures in Mathematics and "miraculously" they became very succesful. Their children have to proceed - suffering and strugling - so they will not depend of miracles! Less succesful parents, which did not have an opportunity of schooling and nave not rthe slightly idea of Mathematics punish their children if they don't show good marks in Mathematics! And peers and society in general regard those that get good grades in Mathematics as potential geniuses, while those that do not do well in Mathematics are regarded as stupid. Socially, this has been instrumental in the selection of elites, as it has been well studied by Pierre Samuel in his classic paper on this theme. On the other hand, the evidence from research showing that both individual and social creativity is enhanced by self-esteem is not taken into account for those that do beautifully in the Arts or in Sports but fail in Mathematics.

Let us introduce at this moment some concepts and reflexions that result from what is now called Social Studies of Science or Science Policy. This is basically the study of the politics of scientific development, the backbone of funding agencies. It is very interesting to analyse the substitution of the colonial discourse by the discourse of aid - both mutltilateral, like UNESCO, and bilateral, like ORSTOM, the British Council and similars. The nature of the deprived populations did not change in the span of less than ten years. The strategies to keep them as

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14 Juan Diez Freyle *Sumario Compendioso de las quentas de plata y oro...Con algunas reglas tocantes al arithmética* Mexico, printed by Juan Pablos of Brescia, 1556. A copy - aparently the only one - is in the Escorial, Spain.

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faithful consumers had to change[16]. But let us not deviate from the main objective of this paper, which is the production of scientific, in particular mathematical, knowledge.

When deciding on investments in Science and Technology, it is natural to expect social benefits. These investments have been substantial, both through funding agencies, either governamental or through aiding agencies, either bi- or multilateral. The outcomes in the so-called Third World have not been encouraging, as recently mentioned by the Director-General of UNESCO. The gap between central nations and peripherical nations in the production of scientific knowledge is enlarging. Over 80% of the benefits of scientific and technological research benefits the First World. "The gap between rich and poor countries is a gap of knowledge" as says Federico Mayor[17]. It is clear that scientific productivity is related to the cultural atmosphere and self-esteem. Self-esteem can hardly prevail among a population deprived of its history. Referring to what was discussed above, the main instrument in the colonial period was to deprive the conquered peoples of their history or to produce a history "favorable" to the conqueror. There is no need to elaborate on the vision of slavery passed on by official history nor to question why Zumbi (1655-1695) is practically unheard of by Brazilian students while Cardinal Richelieu, and of course D'Artagnan, are so familiar.

We may consider, as it is frequent in discussions of policy and specially in the United Nations and other national and international agencies, the production of scientific and technological, particularly mathematical, knowledge as measurable. Scientometrics relies on several indicators and the studies of quantitative history allows us to speak of central nations, those who produce new knowledge, and peripherical nations, those who absorb new knowledge. Production and absorption of knowledge are clearly distinguishable. The sad situation is that the peripherical nations have been slow in absorbing new knowledge. The lack of infrastructure acts as a barrier for this process.[18] The basin metaphor helps to understand the process. The picture speaks for itself. The main producers of knowledge (central nations) are represented by the main stream. The water fertilizes their margins. They will produce their effect in the margins of the affluents (peripherical nations) much later, when the waters have already flown along the stream (thus producing the gap or obsolescence of knowledge). The water (knowledge) do not flow up stream of the affluents. The water of the affluents surely fertilize their margins and will add and contribute to the volume of water of the main stream. This corresponds in this metaphor to the brain drain and the results drain. This is manifest in the classical emigration of academics and, worst, on the orientation of laboratories and research institutions as subsidiary of their major homologous in the central nations.[19] This is clear in the efforts to entice research institutions in the peripherical nations to join major biotechnology research plans. The enticement is normally done by the attractive of sending experts, in many cases scientists with a high reputation, to the periphery for short visits, in offering fellowships, in many cases giving stipends higher than the current national salaries, in sending equipment, in many casesobsolete or already heavily used equipment, and offeringinternational travel to seminars and congresses. This is true in academics and, in the more developed peripherical nations, in industry.

Particularly in mathematics, we have numerous examples of such practices in the post-war period. The presence of monies of the USA Army, Navy and Air Force research agencies, as well as of the NSF, of the CNRS, of the British Council, of the DAAD and other agencies, following the pattern mentioned above, is noticeable. These cases have not been studied in

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[17] Frederico Mayor: Opening Speech at the Conference on "Scientific and Technological Cooperation in Africa", Nairobi, March 1994.

[18] See my note Ubiratan D'Ambrosio "Adapting the Structure of Education to the Needs of Developing Countries" (letter) *Impact of Science on Society* vol. 25, n°1, 1975, p.94.

[19] See my paper Ubiratan D'Ambrosio "Knowledge transfer and the universities: a police dilemma" *Impact of Science on Society* vol. 29, n°3, 1979, p. 223-229.

detail as yet. Both have the common feature of producing human resources and results without any analysis of the capability of the peripherical countries to absorb and to make these resources and results useful for their prioritary needs. Normally this is the result of a lack of qualitative directives in Science Policy of the peripherical nations. Practically every scientific development plan in the periphery is a program entirely based in quantitative goals. Perversely, World Bank, UNDP and other financing agencies rely on, indeed stimulate, plans based on quantitative goals. Clearly, they are easier to check. But the benefits for the poor populations of the peripherical nations is practically nil.

In the basin metaphor, the sources of the rivers, both the main stream and the affluents, correspond to ethnomathematical knowledge. Ethnomathematical knowledge, like the waters, flow fertilizing the margins of the affluent in their way and eventually mixing in a major stream, contributing to this flow. Waters of the main stream do not go up-stream through the afluents.

The notion of progress carried on by the main stream will benefit the margins of the affluent after a long way through difficult land paths - which correspond to the acquisition of knowledge from other socio-cultural and environmental sources. The need of the margins - peripherical cultures - are met by the water of the affluents and only later receive the benefits coming from the main stream. These are useful only in fertile grounds.

An alternative to main stream and affluents would be a large lake, were all the sources contribute equally to the main body of water. Each source producing according to its environmental history and all the waters of the lake fertilizing all the margins.

Erosion of the basin in favor of the creation of a great lake - the deterioration of the current world order - hopefully will lead to a new planetary order.

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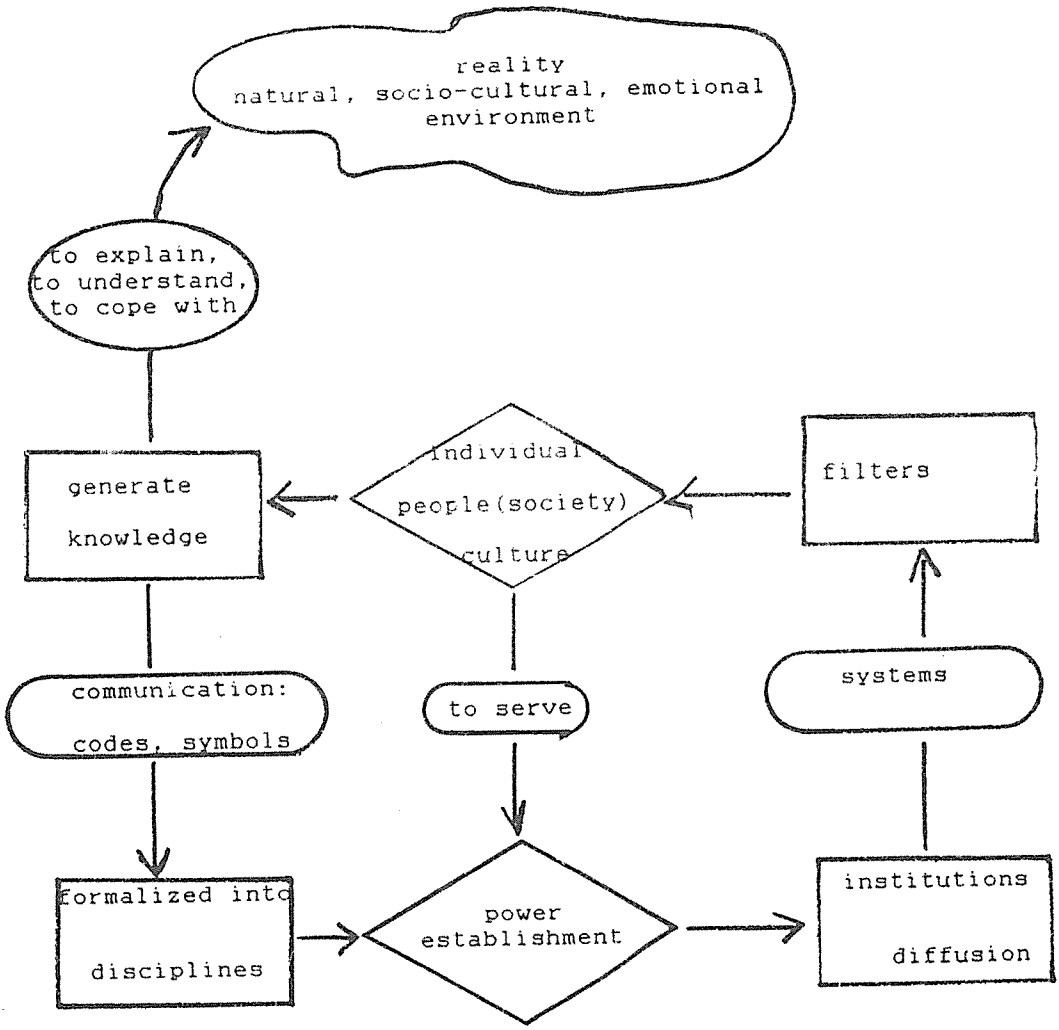
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to serve
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formalized into
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