Ethnoscience and ethnomathematics: a historiographical proposal for non-western science

UBIRATAN D'AMBROSIO

> "Oriental philosophies and religions are of a very different kind from those of the West. I can therefore imagine that there might also exist different modes of thinking even in mathematics.
>
> Yasuo Akizuki, 1960

This paper focus on the social, political and cultural factors in the dynamics of the transfer and the production of scientific and mathematical knowledge in the colonies, as well as on the recognition of non-European forms of science and mathematics, either extant or buried in the colonial process. This is a historiography proposal, which relies on the memory of people and events that survived in a literate era. The methodology puts together scraps of information in non-traditional historic sources and recognizes extant practices, normally called ethno-science and ethnomathematics.

Knowledge and cultural encounters

Science, as generally understood nowadays, emerged in a distinctive form of explaining, understanding and coping with the natural environment in the Mediterranean Basin, since early times. Every culture generated something equivalent to Science, which works satisfactorily in its context. These are corpora of knowledge that have been generated in a particular context, with specific motivations, and that have been and are subject to changes resulting from exposition to other cultures, particular during the colonial era. These corpora of knowledge, generally called ethnosciences and ethnomathematics, have been dealt with inappropriate historiography and equivocated criticism.[1]

These are results of the major challenges facing the human species, which is driven towards survival and transcendence. To survive, which is an action needed

[1] Ubiratan 0'Ambrosio, "A Historiographical Proposal for Non-western Mathematics", Mathematics Across Cultures. The History of Non-Western Mathematics, Helaine Selin (ed.), Dordrecht, Kluwer Academic Publishers, 2000, pp. 79-92.

in the encounter with the other and with nature as a whole. To transcend, which looks into before and after the moment, searching the past and probing into the future.

In order to survive, man needs to generate ways of dealing with the immediate environment, which provides air, water, nourishment, the other and everything needed for the survival of the individual and of the species. These are techniques and styles of individual and collective behavior, which include communication and language.

In search of transcendence, man developed perceptions of past, present and future and their enchaining, and means of explanation of facts and phenomena. These means are memories, individual and collective, myths and divinatory arts, which allow penetrating the future. In memory and myths are the traditions, which include history, religions and systems of values and explanations. The divinatory arts are practices, such as astrology, oracles, logics, such as, for example, the *I Ching*, numerology and the laws of nature (philosophia naturalis), or, using a comprehensive term, the sciences, which tell us what may happen.

A historiography must look into all these categories, memories, myths and the divinatory arts (techniques, behavior, communication, language, traditions, history, religions, systems of values, sciences) to make sense of the past. Very much in line with the *Annales* proposal.[2]

Knowledge is the response to the drives for survival and transcendence. How is knowledge generated, organized intellectually and socially, and diffused? Particularly language and mathematics offer major challenges. Both have grown differently in different cultures. And both have been affected by cultural encounters throughout history.

Particularly important for our analysis are the encounters which occurred after the 15th century between European and non-European cultures. I agree with Urs Bitterli when he reduces the encounter of European and non-European cultures to three basic phases: contact, collision and relationship. He shows that they do not occur necessarily ¡n this order, that they are not mutually excluding and that there has been occurrence of the three types. In some cases the contact lead directly to relationship.[3]

These types of encounter are convenient for understanding cultural dynamics of the encounters, from the beginning of European overseas conquest through early industrial relations.

Current History and Philosophy of Science and of Mathematics focuses on ideas, which synthesize centuries of development in the Mediterranean Basin, enriched by contacts with Africa and the Far East. Historiography is largely based on written sources and relies on names, epochs, dates and places proposed by early historians.

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[2] See Encyclopedia of Historians and Historical Writing, Chicago, Fitzroy Dearborn Publishers, 1999, "Febvre, Luden", pp. 379-380.

[3] Urs Bitterli, Cultures ¡n Conflict. Encounters Between European and Non-European Cultures, 1492-1800, Cambridge, Polity Press, 1989.

Contact, collision and relationship are moments of the same process of the modern European expansion. Although the conquered civilizations possessed scientific and mathematical knowledge, current historiography of science and mathematics is inadequate to recognize the cultural] dynamics of the contacts. Its nature and history are practically unknown. The collision phase resulted in the denial of the forms of knowledge of the conquered. The relationship is marked by an effort to transfer science and mathematics from the European tradition to the colonies.[4]
The condition of consumers of the knowledge produced in Europe continued in the colonies until the transition from the 19th through the 20th century, when a local production of science and mathematics originated in Europe, start to be delineated.

Ethnoscience and ethnomathematics

The great navigations since the 16th century mutually exposed forms of scientific knowledge from different cultural environments. The several ethnosciences, among them European sciences, have been subjected to great changes as a result of the encounters. I will examine some of the consequences of this mutual exposure of cultures.
By ethnosciences I mean the corpora of knowledge established as systems of explanations and ways of doing, which are accumulated through generations in specific cultural environments.
Particularly important for us is ethnomathematics, which is corpora of knowledge derived from quantitative and qualitative practices, such as counting, weighing and measuring, sorting and classifying. The same as Western science and mathematics, ethnosciences and ethnomathematics have a symbiotic relation.
Both are not new disciplines. Rather, they are part of a research program on history and epistemology. The pedagogical implications are obvious. Both research and educational programs take into account all the forces that shape a mode of thought, in the sense of looking into the *generation, organization* (both intellectual and social) and *diffusion* of knowledge.[5]
The research program, typically interdisciplinary, brings together and interrelates, results from the cognitive sciences, epistemology, history, sociology and education. An essential component is the recognition that science and mathematics are intellectual constructs of mankind in response to needs of survival and transcendence.

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[4] Ubiratan D'Ambrosio, La Transferencia del Conocimiento Matemático a las Colonias: Factores Sociales, Políticos y Culturales, LLULL, Vol. 22, 1999, pp. 347-380.
[5] Ubiratan D'Ambrosio, *Several Dimensions of Science Education: A Latin American Perspective,* Santiago, CIDE/REDUC, 1991, p. 119.

The need for an intellectual framework to organize the corresponding systems of codes, norms and practices gave rise to many aspects of science and mathematics.[6]

In the research program, particular attention is given to those dimensions of knowledge, which bear some relation to what became known as the several discipline of science and mathematics in European civilization after the 15th century.

Ethnoscience, both as corpora of knowledge and as pedagogical practices, is supported by the history of science and reflect the dynamics of cultural acquisition. Some examples illustrate this.

All over the World, much of the weather explanations and predictions, agriculture practices, processes of cure, dressing and institutional codes, culinary, and commerce, carne from the European tradition developed in the Middle Ages and the Renaissance. But we see, all over the World, practices performed in a very distinctive. These practices, which have their origins in native communities, are significantly modified as a result of mutual exposition of cultural forms since colonial times. For example, it is common to see indigenous peoples in the Americas using Indo-Arabic numerals, but performing the operations from bottom to top, explaining that this is the way trees grow. But it is also common to identify, in the more advanced notions, the influence of this mutual exposition in everyday life and practices.

In daily life, practices, which are scientifically based, are easily recognized. This is evident by looking into professions that require some scientific knowledge and mathematical abilities.

Practices and perceptions of learners are the substratum upon which new knowledge is built. Thus, new knowledge has to be based on the individual and cultural history of the learner and it has to recognize the diversity of extant cultures, present in specific communities, all over the world. This is the essence of a new educational posture called Multicultural Education.

A new educational posture depends on a new historical attitude which recognizes the contribution of past cultures in building up the modern world and modern thought, and which avoids omissions and errors of the past treatment of cultural differences.

We easily identify two categories of scientific knowledge:

- Scholarly (or "formal" or "academic") science, supported by a convenient epistemology, and whose practice is restricted to professionals with specialties;
- Cultural (or "practical" or "popular" or "street") science, or ethnosciences.

[6] Ubiratan D'Ambrosio, "Ethno-mathematics, the Nature of Mathematics and Mathematics Education", *Mathematics, Education and Philosophy: An International Perspective,* Paúl Ernest (ed.), The Falmer Press, London, 1994.

These categories are closely related and their main distinction refers to criteria of rigor, to the nature, domain and breadth of its pursuits, which is "how well" they respond to the needs of survival and transcendence.

For example, pre-Columbian cultures had different worldviews. This is inbuilt in their mythology, religion and, of course, in their complex of explanations, and as a consequence, different styles of doing their measurements and computations.[7] These practices are still prevalent in some native communities. Land measurement, as practiced by peasants in Latin America nowadays, comes from ancient geometry transmitted to medieval surveyors, since land property and measurement (geometry) were strange to Pre-Columbian cultures.

Most Amazonian tribes have counting systems that goes as "one, two, three, four, many". And that is all, since with these numbers they can satisfy all their needs.[8] We also recognize important ways of dealing with pottery, tapestry and everyday knowledge with strong mathematics characteristics in several cultures.[9] The same with African cultures.[10] The people from these cultures have no problems at all in assimilating the current European number system and deal perfectly well with counting, measurement and money *when* trading with individuals of European culture. Another example comes from Africa, where the people deal with numbers and counting according to their specific cultural background.[11]

The high prestige of science comes mainly from its recognition as the basic intellectual instrument of progress. It is recognized that modern technology depends on science and that the instruments of validation in social, economic and political affairs, mainly through storing and handling data, are based on science and mathematics. Particularly important in this respect is statistics. This evidently brings to science an aura of essentiality in modern society. There is a general feeling that there are practically no limits to what can be explained by science. Many of the applications that give such a prestigious position to science are part of various forms of cultural dynamics.

The same is, probably, more clearly seen in technology. The efforts of the early colonizers to adapt technology developed in Europe to the new lands is responsible for many advances, particularly in mining, agriculture and medicine.[12]

Another important example on how the cultural dynamics of the encounter is seen in the transfer of applied science and technology is the process of urbanization. How to meet the challenge of founding cities in the new lands?[13]

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[7] See the recent book by Andrea C. Schalley, *Das mathematische Weltbild der Maya,* Frankfurt am Main, Peter Lang, 2000.

[8] *Native American Mathematics,* Michael Closs (ed.), University of Texas Press, Austin, 1986.

[9] Marcia Ascher, *Ethnomathematics. A Multicultural View of Mathematical Ideas,* Pacific Grove, Brooks/Cole Publishing Company, 1991.

[10] Paulus Gerdes, *Ethnomathematics and Education in Africa,* Institute of International Education/Stockholms Universitet, Stockholm, 1995.

[11] Claudia Zaslavsky, *Africa Counts: Number and Pattern for Teachers,* Lawrence Hill, New York, 1979.

[12] See the interesting paper by Nicolas Garcia Tapias, "The Repercussion of Spanish Technology in the Discovery of the American Continent", *ICÓN,* vol. 5, 1999, pp. 113-127.

Practices are generated, organized and transmitted informally, the same as language, to satisfy immediate needs of a population. They are incorporated in the pool of common knowledge that keeps a group of individuals, a community, a society together and operational, and this is what is called culture. Culture thus manifests itself in different, obviously interrelated, forms and domains. Cultural forms, such as sets of explanations, language, mathematical practices, religious feelings, values, family structure, dressing and behavior patterns, are thus diversified. They are of course associated with the history of the groups of individuals, communities and societies where they are developed. A larger community is partitioned into several distinct cultural variants, each owing to its own history and responsive to differentiated cultural forms.

Some remarks on historiography

History, as a major academic discipline, carries with it an intrinsic bias, which makes it difficult to explain the ever present process of cultural dynamics that permeates the evolution of mankind. This paves the way for paternalism and arrogance, for intolerance and intransigence. And clearly interferes with the understanding, for different cultural groups, of each other processes of building up their cultural realities when trying to satisfy their needs of survival and transcendence.

These biases have been methodological as well as ideological, particularly in the History of Science. Helge Kragh says "History of Science has its own 'imperialism' that partly reflects the fact that viewed historically and socially science is almost purely a western phenomenon, concentrated on a few, rich countries. While science may be international, history of science is not."[14]

This seems to be almost unavoidable in the framework of historiographies that rely on reductionist approaches, such as the case of the various supposedly autonomous histories, in particular in the History of Science. The mere fact that to pursue historical analyses one talks about the sciences, such as Physics, Chemistry, Mathematics, as distinct from Religion, Art, Politics, obviously impedes the understanding of the processes of evolution of ideas and methods, of reflection and action, which underlies man's struggle to find explanations, to understand and cope with its environment, and of conviviality with nature.

Reductionism, which characterizes several of the so-called autonomous histories and also histories based on facts and names, on places and dates, naturally derives from the prevailing ideology and justify cur-rent actions. Even when we move a step further than narrative history and go to historiography, the facts prevail

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[13] See the important study of José Sala Cátala, *Ciencia y Técnica en la Metropolización de América,* Theatrum Machinae, Ediciones Doce Calles/CSIC, Madrid, 1996.

[14] Helge Kragh, *An Introduction to the Historiography of Science,* Cambridge Univ. Press, Cambridge, 1987, p. 111.

over the processes and we may be led to be satisfied with the false impression of having approached the past because we have verified data and described facts.
Historiography focused on a problem should never lose the view of all the forces, which play in the historical reality, thus avoiding the unilateral approach of the specialist and the reductionist flow to a few elements. Armando Saitta asks for the historian to look into "What to-day isn't but tomorrow will be".[15] He clearly proposes a global history. When he refuses the history of the "if", he opens the way to an evaluation of all the alternatives which were present in the process and he claims that the one alternative which have succeeded should not imply the rejection of he others. E. H. Carr has the same opinion when he says that the historical moment in which several alternatives were open does not imply abandoning those that did not succeed, but rather looking into the reason for which some did not succeed and what was the cost of this decision.[16]
Paraphrasing Miguel León-Portilla, it is a matter of listening also to the loser.[17] History has been mostly the history of the winners. Indeed, to remove the history of the loser was the most efficient intellectual tool of the colonizer. As recognized by Markus P.M. Vink, the development of science and technology in the 19th century gave material tools, such as quinine, vaccination, the machine gun, steamboat, railroad, telegraph, which became fully integrated in the knowledge brought by the colonizer (winner) to supersede the knowledge of the conquered (loser).[18]
This is particularly true in the history of the sciences of the losers. The mere fact is that science means power, since, as every other divinatory art, it anticipates what did not yet happen. This association of science with power is seen very clearly in the history of European science.[19]
The dawn of modern science is identified with the modern geography of the world, and the granting of privileges for those capable of mastering modern science and technology. How did this privileged role of scientists come into being? Why conquered and colonized still have problems in mastering science and technology? Why have science and technology progressed so rapidly and in this process have left aside, indeed eliminated, social and, above all, ethical concerns, thus paving the way for enormous social, political and environmental distortions? These questions are germane to the concept of knowledge itself.

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[15] Armando Saitta, *Il programma della Collezione storica,* Laterza, Bari, 1955, p. 12.
[16] E.H. Carr, *What is* History?, Penguin Books, Harmondsworth, 1968.
[17] Miguel León-Portilla, "Visión de los Vencidos (Crónicas Indígenas Mexicanas)", *Historia* 16, 1985.
[18] For a comprehensive view of the late Western colonial expansion, see Markus P.M. Vink, "New or High Imperialism, 1870-1914", Process and Patterns, World History bulletin, vol. XVII, núr. 1, Fall 2000, pp. 16-31.
[19] The silence of European historians of science about John Flamsteed (1646-1 719) is an example. See David Clark and Stephen P.H. Clark, *Newton's Tyranny. The Sup-pressed Scientific Discoveries of Stephen* Cray *and John Flamsteed,* W.H. Freeman, New York, 2000.

Building-up scientific knowledge

We see knowledge as emanating from the people, essentially generated by individual as a result of man's drive towards explaining, understanding and coping with the immediate environment and with reality in general, reality understood in its broadest sense and in permanent change as a result of man's own action. This drive, with the ultimate objectives of survival and transcendence, is obviously holistic and dynamically subjected to a process of exposure to other members of society, people.

Thanks to communication, both immediate and remote in time and space, the knowledge thus generated goes through a process of codification, intertwined by an associated underlying logic, inherent to the people as a form of knowledge — some call wisdom. The modes of communication and the underlying logic are recognized as the result of the prevailing cognitive processes. Cognitive evolution, related to environmental specificity, gives rise to different modes of thought and different underlying logic, communication and codification. Hence knowledge is thus organized, intellectually, that is, structured and formalized subjected to specificities of cultural nature. And through the cultural process of sharing knowledge and according behavior, it is socially organized. It becomes a corpus in the cultural framework.

Power structure, which itself rises from society as a form of political knowledge, appropriates, indeed expropriates, structured knowledge and organize them in institutions. In this form, and under the control of the establishment and the power structure, which mutually support each other, knowledge is given back to the people, who in the first instance generated it, through systems and filters which are designed to keep the established power structure. It is the diffusion of knowledge.

The generation, organization and diffusion of knowledge is clearly a holistic process subjected to the dynamics of change. This is the essence of the research program on the history of science, which I call Ethnomathematics. It recognizes that mutual exposure of distinct approaches to knowledge, resulting from distinct environmental realities, is global, embracing the entire cycle of the generation, organization and diffusion of knowledge.

The process of cultural dynamics which takes place in the encounters is based on mechanisms which balance the process of change, which I call *acquiescence* — that is, the capability of consciously accepting change (modernity)— and the cultural *ethos* —which acts as a sort of protective mechanism against change that produces new cultural forms.

This behavior can be traced back throughout the entire history of mankind. These conceptual tools are close to the ethos and schismogenesis, introduced by Gregory Bateson in dealing with cultural contact and enculturation.[20]

In the encounter of the two worlds (Europe and America) this was violated in many instances. The origin of these violations may be related to distinct views of nature.

[20] Gregory Bateson, 5teps to an *Ecology of Mind,* Ballantine Books, New York, 1972.

A scientific conceptualization, which resulted from an intertwining of medieval Judeo, Christian and Greco-Arabic thought, and developed in Europe, lead man to look at nature and at the universe as an inexhaustible source of richness and to exploit these resources with a mandatory drive towards power and possession.[21]
This behavior towards nature and life has lead man to favor a single model of development, hence to ignore the cultural, economical, spiritual and social diversities, which constitute the essence of our species.
These reflections question the set of current concepts and models, and calls for the acceptance of the idea that survival depends of a global and holistic view of reality. This demands a radical change, which applies to all levels of knowing and doing. We are thus lead to look for radical changes in our models of development, of education and of civilization, based in the recognition of a plurality of models, of cultures, of spirituality and of social and economical diversity, with full respect for each one of the distinct options.

Final remarks

The conquest and colonization had, as a consequence, an enormous influence in the course of development of the civilization. The chroniclers of the conquest tell of they have seen and learnt. They mention absolutely different ways of explaining the cosmos and the creation, and ways of dealing with the surrounding environment. Religious systems, political structures, architecture and urban arrangements, sciences and values were, in a few decades, suppressed and replaced by those of the conqueror. A few remnants of the original behavior of these cultures were and still are outlawed or treated as folklore. But they surely integrate the cultural memory of the peoples descending from the conquered. Much of these behaviors are easily recognized in everyday life.
Science and mathematics, as human endeavor, are not different. This is one focal point of the research program called, Ethnomathematics, which deals with the generation, the intellectual and social organization and the diffusion of different ways, styles, modes (tics) of explanation, understanding, learning, coping with and probing beyond (mathema) the immediate natural and socio-cultural environment *(ethno).*[22] Obviously, ethnoscience is part of this.
The early colonizers of the Americas, the Spanish and the Portuguese, paved the way for the French, the English and the Dutch colonizer and later on for Africans, Europeans and Asiatic immigrants. With them carne new forms of coping with the

[21] It is a good theme to compare the efforts of historians of science to insert ecological concerns in the evolution of Western thought and these views on ethno-science. Particularly illustrative of these questions is the paper by Andrew Cunningham, "Science and Religion in the Thirteenth Century Revisited: The Making of St. Francis the Proto-Ecologist. Part I: Creature not Nature", *Studies in History and Philosophy of Science,* vol. 31A, núr. 4, December 2000, pp. 613-643.
[22] Ubiratan D'Ambrosio, *Etnomatemática. Arte ou Técnica de Explicar e Conhecer,* Editora Ática, Sao Paulo, 1990. A translation is available, *Ethnomathematics. The Art or Technique of Explaining and Knowing,* Patrick B. Scott (tr.), NMSU/ISGEm, Las Cruces, 1998.

environment, of dealing with daily life, and new ways of explanation and learning. The result was the emergence of a synthesis of different forms of knowing and explaining which were generated by and available to the different communities, to workers and to the people. We recognize the emergence very soon of new religions, of new cuisine, new music, new arts and new languages. All of these absolutely interrelated as a synthesis of the cultural forms of the ancestors.

Particularly in the Americas, the variety and peculiarity of the expositions of cultures and the specificity of the population migrations re-veal an effort of the colonizer to transfer, with minor adaptations, the forms of social, economical and political organization and administration prevailing in the metropolises, including schooling and scholarship (academies, universities, monasteries). The new institutions in the Americas were based on the styles prevailing in the metropolises, mostly under influence, and even control, of religious orders.

This poses the following

> Basic *question:* What are the relations between the producers and consumers of cultural goods?

This guides a proposal for a historiography of science and mathematics, which I have called "the basin metaphor".[23]

Although this is a question affecting the relations between academia and society in general, hence between the ruling elite and the population as a whole, it is particularly important for understanding the role of intellectuals in the colonial era.

Curiously enough, the factors influencing the consumption of what we might call academic science and mathematics produced in an alien cultural environment, and what "outsiders" of the profession —that is, non-scientists— have to say about science and mathematics, which affect their everyday life, have not been given attention in the prevailing historiography.[24]

It is important to incorporate to the History of Science and Mathematics, in an essential way, not as mere anecdotes, the views of aliens —cultural and academic— about science and mathematics. This broader look, suggested by new historical scholarship, comes under severe at-tack, in what became to be known as the Science Wars.[25]

The essence of my historiographical proposal is the recognition that this cannot be done unless we examine simultaneously techniques, behavior, communication, language, traditions, history, systems of values, religions and the sciences. They

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[23] Discussed in the paper in note 1 above.

[24] See Ubiratan D'Ambrosio, Mathematics and Literature, *Essays in Humanistic Mathematics,* Alvin M. White (ed.), The Mathematical Association of America, Washington D.C., 1993, pp. 35-47.

[25] See the issue devoted to the theme "Science Wars" of the 5oc;a/ Text, pp. 46-47, Spring/Summer 1996. The issue has very interesting papers. Regrettably, attention was given only to the hoax of Alan Sokal. As a consequence there were renewed attacks on Afrocentrism, warnings against a "new dark age of irrationalism" and other controversial disputes going on in the academic world. All this that might be interpreted as a form of intellectual fundamentalism is nothing but a defensive posture against the challenge, which the current epistemological order is facing.

come together. The recognition of other systems of generation, of intellectual and social organization and of diffusion of ways, styles, modes of explanation, understanding, learning, coping with and probing beyond the immediate and the remote natural and socio-cultural environment, is the only possibility of escaping the arrogance associated with the Western concept of truth. Fundamentalism, which is the result of such arrogance, is best described by Sri Aurobindo (1872-1950):

> For Western Philosophy a fixed intellectual belief is the most important part of a cult, it is the essence of its meaning and it is what distinguishes it of others. Thus, formulated beliefs make true or false a religion, according to agreeing or not with the beliefs of its critics.