From the era of the navigations to the era of high technology as illustrated by Ethnoscience and Ethnomathematics [1]

by Ubiratan D'Ambrosio

http://sites.uol.com.br/vello/from.htm

This talk addresses the fact that the great navigations since the 16th century mutually exposed forms of scientific knowledge from different cultural environments. The several ethnosciences envolved in the encounters, which obviously include European Science, have been subjected to great changes as a result. In this paper I will draw some lessons from the consequences of this mutual exposure of cultures and venture into some reflections about the future as a consequence of the impressive changes we have in communication and information, which are essential for education.

Science and Mathematics, which are the backbone of the Modern World, invites for a good reflection on how they came to the state they are now. The universality of Western Science and Mathematics is a direct result of the globalization initiated in the 15th century with the great navigation. This was possible thanks to the most developed technology available in that period. As a result, we witnessed a growing universalization of school curricula all over the world. With small differences, schools all over the world practice the same curriculum. Will the new technologies of communication and information reinforce this trend? How does multicultural education, particularly in Science and Mathematics, fit in this new trend towards globalization?

What will be the impact of these new tools coming from information and communication technologies on ethnoscience and ethnomathematics, which are, together with Language, the core of multicultural education?

Although the main objective of this conference is the impact of modern technologies in education –– and indeed we are practicing the new –- a view of history is fundamental. We feel easier to enter the new with an understanding of the old. Our critical view of the past is the better guide for the future.

Ethnoscience and Ethnomathematics in daily life

I work with two definitions which should be stated in the very beginning of this paper.

Ethnoscience is the corpus of knowledge established as systems of explanations and ways of doing accumulated through generations in distinct cultural environments.

ETHNOMATHEMATICS is the corpus of knowledge derived from quantitative and qualitative practices, such as counting, weighing and measuring, sorting and classifying. As with academic Western Science and Mathematics, the two have a symbiotic relation.

Both are not new disciplines. Rather they are research programs 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.

The research program, typically interdisciplinarian, brings together and interrelates, results from the cognitive sciences, epistemology, history, sociology and education. An essential component is the recognition that mathematics and science are intellectual constructs of mankind in response to needs of survival and transcendence. As a result, different cultures have organized systems of codes, norms and practices. [2]
Particular attention will be 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.

In the rest of this paper, unless there are specificities, I will refer only to Ethnoscience, which naturally includes Ethnomathematics.

Ethnoscience, both as a corpus of knowledge and as a pedagogical practice, 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, came 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.

Will these practices survive in the era of high technology? Most probably they will give rise to different practices, which will be the result of broad communication. They will be the fusion of traditional practices coming from all over the world. Differently than the knowledge brought by the conquerors and colonizers, the new knowledge will be collectively constructed.
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 be

recognized 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.

But this new educational posture depends on a new historical attitude is needed 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 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. [3] These categories are closely related and their main distinction refers to criteria of rigor, to the nature, domain and breadth of its pursuits, that is to what and how much one can do with them.

Land measurement is particularly interesting. Land measurement, as practiced by peasants in Latin America, comes from ancient geometry transmitted to medieval surveyors. Land property and measurement (geo-metry) is strange to Pre-Columbian cultures and they had different styles of doing their measurements and computations. Some of these practices are still prevalent in some native communities.

Now, precision and dimension of the land require other forms of measurement. For example, Amazonian tribes have been receiving large chunks of land as their territory. The concept of territorial demarcation is not present in their culture and they do not means to proceed this demarcation. They acquire the new knowledge in order to exert their possession of the land. And we see they are formulating a new knowledge which incorporates the most advanced technology. Of course, initially a few natives acquire this knowledge and this is rapidly assimilated, through their educational systems, by the tribe.

Very interesting is the situation of counting. 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. [4] We also see important ways of dealing with pottery, tapestry and everyday knowledge with strong mathematics characteristics in several cultures. [5] The same with African cultures. [6]

What we see is that 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. Carpenters, brick and carpet layers all over the world use very specific geometry in their work. They have to cut and pieces produced in the usual geometrical forms, such as squares, rectangles, regular polygons, and adjust them to the surface to be covered, practicing optimization techniques. The practical arithmetic of street vendors in Northeast Brazil is a peculiar way of dealing with money for which face value is not significant. An interesting situation occurred as a consequence of the high inflation in Brazil until three years ago. A new currency was introduced: "new cruzeiro (NCr$)" and its worth was one thousand "cruzeiros

(Cr$)", that is, NCr$1.00 = Cr$1,000.00. New bills were put in circulation before the old ones were destroyed. Thus a new bill showing "10" would have more value than an old bill showing "100". [7] Another example comes from Africa, where the people deal with numbers and counting according to their specific cultural background. [8]

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 which give science such a prestigious position are part of various forms of cultural conflict.

New technologies, particularly the generalized access to television, will give marginal populations - not only indigenous, but equally urban communities in the lower economic strata - access to information which is presented in the form of graphs and statistics. With an increasing presence of computers in school systems, the access to data asks for a new kind of mathematics which is assimilated together with informally acquired knowledge. A similar phenomenon as the appearance of the Vulgate in medieval times.

Studies of ethnoscience and ethnomathematics are motivated by the demands of the natural and cultural environment and are present everywhere. It is a fact that just about everybody deals with mathematical practices, incorporated in daily routines, even without recognizing it. When walking or driving, people memorize routes, in most cases optimizing trajectories, which is a practice of a mathematical nature. Also when dealing with money, with measurement and quantification in general, we recognize an intrinsic mathematical component. The same with the capability of classifying, ordering, selecting and memorizing routines.

These 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 which 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 language, mathematical practices, religious feelings, 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.

The key point is that the vision of the world, which gave origin to Science and Mathematics, was limited, both to the conquerors (Western cultures) and the conquered. The development of Western Science and Mathematics have also been limited as a result of precarious views of the world –-

weak technology –- and of a refusal to “listen” to the conquered, which was necessary in the process of imposing the rule of the conqueror. This game of power, seen also in the recent political play, becomes unnecessary in the global world. [9]

The access to new technology becomes essential for the existence of the production system. A simple arithmetic shows that the increase in production requires increased buying power. There is future for the producers without the buyers. Unemployment decrees the end of the production. Similarly, information and communication technologies require increasing access to the system.

Building-up scientific knowledge

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 which 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.

The dawn of Modern Science is identified with the modern geography of the world, and the appearance of privileges for those capable of mastering Modern Science and Technology. How did this privileged role came 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 progress has 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.

I see knowledge as emanating from the people, essentially a product of man's drive towards explaining, understanding and coping with his 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, obviously holistic, is dynamically subjected to a process of exposure to other members of society -- people -- and thanks to communication, both immediate and remote in time and space, 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 structured and formalized subjected to specificity of a cultural nature. 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.

The generation, transmission, institutionalization and diffusion of knowledge is clearly an holistic approach to knowledge and to the dynamics of change. This is the essence of the research program on the History of Science which I call ”Ethnomathematics”. [10]

The disciplinary approach to knowledge in general focus on cognition, epistemology, history and sociology. This clearly makes it difficult to understand the dynamics of change. Mutual exposure of distinct approaches to knowledge, resulting from distinct environmental realities, is global, embracing the entire cycle from the generation through the diffusion of knowledge.

The process of cultural dynamics which takes place in the exposure 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. [11]

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. 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.

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. Thus we are 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.

The encounter of cultures

What we foresee with the generalized use of the technologies of communication and information is an encounter of cultures. Practically, no important event in the world goes unnoticed by the entire mankind. This happened before. Which lessons can we learn from the previous encounter, usually referred to as the conquest?

The European navigators of the end of the 15th and early 16th centuries reached all of America, Africa, India and China. In the case of Africa and in Asia, previous contacts with civilizations which had shared, before, many encounters among themselves and with Europeans. Thus the encounters of the 15th and early 16th centuries were, indeed, an amplifications and deeper contacts. But meeting the “new”, the unknown, the unexpected, was experienced by Columbus and the Spaniards, in 1492 and the subsequent voyages.

Although earlier contacts with the Americas are known, the motivations and behavior of earlier navigators was completely different from the Spanish and Portuguese, and afterwards the English, French and Dutch. [12]

As I said above, America and, to some extent Africa, were more surprising to Europeans than what was seen in lands which had been reached before by land routes. Particularly, America showed peoples with new forms of explanation, of rituals and of societal arrangement. Reflections on the so-called Natural Philosophy or the Physical Sciences, particularly Astronomy, were part of the overall cosmovision of the Pre-Columbian civilizations. In other words, the scientific establishment and scientists, surely present in the society of the conquered cultures, have not been recognized as such by the conquerors. One of the earliest registers of these cultures, Fray Bernardino de Sahagún writes, in the 16th century, that "The reader will rightfully be bored in reading this Book Seven [Which treats Astrology and Natural Philosophy which the naturals of this New Spain have reached],...trying only to know and to write what they understood in the matter of astrology and natural philosophy, what is very little and very low". [13] The important report of Sahagún explains much of the flora and fauna, as well as of medicinal properties of herbs of Nueva España. But he does not give any credit to indigenous formal structured knowledge. This is typical of what might be called an epistemological obstacle of the encounter.

Another important book is the Sumario compendioso ... con algunas reglas tocantes al Aritmética by Juan Diaz Freyle, printed in Mexico in 1556, the first arithmetic book printed in the New World. It has a description of the number system of the Aztecs. But this book soon disappeared of circulation and the Aztec arithmetic was replaced by the Spanish system.

Much research is needed on the Science of the encounter. But this needs a new historiography, since names and facts, on which current history of science heavily rely, have not been a concern in the registry of these cultures. A history "from below", which might throw some lights in the modes of explanation and of understanding reality in these cultures, have not been common in the History of Science.

There is some more availability of sources for the history of the natural and health sciences.

The importance of the encounter for the health sciences is easily recognized. The main sources are the register of diseases which decimated the conquered populations, particularly smallpox, and

reciprocally brought new diseases to Europe, such as syphilis, and the implantation of health systems in the colonies. [14]

We have to keep present that the populations of Latin America have always been multicultural, with successive migrations of distinct cultural groups in Pre-Columbian times. This internal migration was followed by waves of conquerors, of colonizers, of creoles (whites born in the new lands), of Africans (brought as slaves, with distinct cultural backgrounds) and of European and other immigrants (including contingents from the Middle-East, India and the Far-East), roughly in this order. The New World, particularly Latin America, is a cultural cauldron.

Let us look into the late 15th and early 16th centuries, the moment when Europe was laying the ground for the Modern Science, which would be firmly established with the publication of Newton's Principia. It should be noticed that much of the supporting observations given by I. Newton to his theories are the result of observations made in the New World, in particular Brazil. The early mathematicians who went to the newly conquered lands were all proficient astronomers, with important climatic observations.

Medical practices in the Iberian peninsula in the 15th century represented, as did most forms of knowledge, a synthesis of Greco-Roman Hippocratic and Galenic traditions, under the dominant position of the Catholic Church. The Islamic influence, a result of almost seven hundred years of domination, was strong. What was going on before Islam we learn from the writings of Isidore de Seville (b.ca 560; d.636), mainly in his works Etymologiae and De Natura Rerum, both highly influential during the Middle Ages. They bring together existing medical and related knowledge in a consistent encyclopedic style. [15]

Islam brought to the peninsula a distinct renewal of scholasticism. In the period before the navigation, the Iberian peninsula was subjected to a renewed influence of Greek thought brought by the Islamic rulers, which favored an important presence of Jewish scholars and practitioners. With the reconquest under way, the tolerance of the Catholic kingdoms towards converted Jews ("Cristãos Novos") allowed the transmission of Islamic science, particularly Medicine. Converted Jews were usually practitioners of a humble socioeconomic status, by doctors and apothecaries. At the same time, the resistance of the Catholic Church focused on the internal struggles of Christianity itself, thus building up formidable instruments of conservatism. At the same time that a New World was open to them, conservatism was imposing the grips of traditional thinking. It is well known that all the Portuguese expeditions to the coast of Africa used to bring a number of black "informants" to the Portuguese court. These were usually versed individuals in the Sciences as practiced by the Africans. The same is true after the voyages to Brazil.

On the other hand, restrictions to modern development in the Iberian peninsula were strong. For example, anatomy was banished due to restrictions on dissection. This scientific restrictions plus the waves of Inquisition Tribunals against Jews and New Christians stimulated a brain drain

particularly intense in the medical profession. European centers and also to the new possessions overseas were, even under the same government, these measures a safer refuge.

The voyages and excursions into the newly conquered lands demanded extensive participation of practitioners, with great flexibility in the use of their knowledge in very different situations. Clearly, it was needed scientific curiosity and research methodology to face and understand new diseases and to propose new cures. The arrival and departure of ships from and to the New World were always a situation demanding more medical care, in most cases dealing with hitherto unknown diseases.

The early flow of information from Portugal and Spain to Europe was mainly the result of immigrants going to work in other European countries and navigators of other nationalities working in Iberian ships. The colonialist ventures of England, France and Holland would bring to Europe new sources of knowledge from the Americas. Particularly relevant was the information coming to Holland through the Dutch settlement in Northeast Brazil from 1630 to 1661, specially from 1637 to 1645, while the Governor and Captain-General of the colony was Johan Maurits of Nassau-Siegen (1604-1679). Nassau brought to Brazil artists and scientists of good standing and capable of reporting on the new world.

Other visitors to Latin America in the early colonial period surely have marked the imagination of intellectuals of the sixteenth and seventeenth centuries, the moment when Modern Science was setting its roots.

Conclusion

No one can deny that the encounter of cultures has opened for the whole of mankind new intellectual and material dimensions and new possibilities of a high quality of life. Regrettably, no one can deny either that many distortions in the course of 500 years after the major encounter of the civilizations in each side of the Atlantic have instead resulted in these enormous new possibilities only benefiting a few and threatening the planet of destruction.

An unbiased view of history will allow to recognized this and to prepare for the next encounter. Particularly important, as mentioned above, were the advances in the health sciences. This is obviously related to the environment.

Probably the most important impact of the new technologies will happen in environmental and health sciences. Clearly, meteorological studies can be performed as a routine in classroom. A reorganization of mathematical curricula to understand climatic specificity of each region of the planet will be needed. Surely, matters not present in the mathematics curriculum, will be needed. Data analysis stretching over different period of times will be novel in the mathematics classroom. Monitoring, essential for the modern world but absent from the curricula, will give school mathematics a new dynamics.

In the health sciences, incidence of diseases will help students to understand the concept of preventive health care, undoubtedly a most urgent change in medicine. Epidemics can be monitored through school practice with the information technologies, which have obvious implications for public health.

Environmental issues can equally be treated in the schools. The growing field of environmental mathematics will find, in the schools, a possibility, as a consequence of communication and information technologies.

It is clear that all the examples mentioned above as new directions for school mathematics are loaded with cultural issues and at the same time would not be possible without information and communication technologies.

How long it will take for these trends to be fully incorporated into the school systems? Much less than most teachers realize. An easy exercise will show that the price of the equipment has been steadily decreasing, while the cost of traditional school equipment (buildings and books) have been increasing. Teaching power, understood as the amount of attention given by a teacher to individual students, can be highly increased if the routine and repetitive practices are left to videos and disks. More time for group work, which may go beyond the classroom and the school boundaries are possible and desired. Boundaries in schools, communities, states, countries are naturally overcome with the new technologies.

What is needed? Teachers will. The equipment is generally underused. There is, worldwide, a large amount of available equipment in schools not being properly utilized. Will means not only having access to the equipment but readiness to embrace the new. This requires courage to leave much of what is currently part of the curriculum and bring new mathematics into the classroom. The teacher can hardly do this without exchanging views and ideas with colleagues. Particularly in small and remote communities, the new technologies of communication and information open possibilities which were hitherto unthinkable.

We have to practice the future now. The denial of the idea of future is to wait the future to enter into it.

Notas

[1] Plenary talk in the First Virtual Conference of the Australian Association of Mathematics Teachers" [http://www.aamt.edu.au], October 16, 1998.

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

[3] Many scholars do not agree with the use of "cultural science". We might say ethnoscience.

[4] Michael Closs: ed., Native American Mathematics Austin: University of Texas Press, 1986.

[5] Marcia Ascher: Ethnomathematics. A Multicultural View of Mathematical Ideas, Pacific Grove: Brooks/Cole Publishing Company, 1991.
[6] Paulus Gerdes: Ethnomathematics and Education in Africa Stockholm: Institute of International Education/Stockholms Universitet, 1995.
[7] Geoffrey Saxe: Culture and Cognitive Development. Studies in Mathematical Understanding , Hillsdale: Lawrence Erlbaum Associates, Publishers 1991.
[8] Claudia Zaslavsky: Africa Counts: Number and Pattern for Teachers New York: Lawrence Hill, 1979.
[9] As an example I give the lessening measures of forbidding use of national languages, as it happened in Franco's Spain.
[10] Ubiratan D'Ambrosio: ETNOMATEMÁTICA. Arte ou Técnica de Explicar e Conhecer, Editora Ática, São Paulo, 1990. An English translation, by Patrick Scott, ETHNOMATHEMATICS, is available by ISGEm/NMSU, Las Cruces, 1998 [order from pscott@NMSU.Edu.
[11] Gregory Bateson: Steps to an Ecology of Mind, Ballantine Books, New York, 1972.
[12] See the careful study of Ivan Van Sertima: They Came Before Columbus, Random House, New York, 1976 and the reports on the voyages of the Chinese monk Huei Shen in the 5th century to Mexico. See the communication of Juan Hung Hui: "Tecnologia Naval China y Viaje al Nuevo Mundo del Monje Chino Huei Shen, III Congreso Latinoamericano y III Congreso Mexicano de Historia de la Ciencia y la Tecnologia, Ciudad de Mexico, 12-16 Enero 1992.
[13] Fray Bernardino de Sahagún: Historia General de las cosas de Nueva España, 2 vols., Alianza Editorial Mexicana, Mexico, 1989; Tomo 2, p.478.
[14] Ubiratan D'Ambrosio: "Specificity of the health sciences in the Iberian peninsula at the time of the discoveries", Advances in Gynecology and Obstetrics, The Proceedings of the XIIth World Congress of Gynecology and Obstetrics, (Rio de Janeiro, 1988), eds. P. Belfort, J.A. Pinotti and T.K.A.B. Eskes, Parthenon Pub. Co., London, 1988; pp.29-32.
[15] For a good account of Isidore's contribution, see the monograph by W.D. Sharpe: "Isidore de Seville: the medical writings", Trans. Am. Phil.Soc., New Series, vol. 54; pp.1-75.