

THE PROGRAM ETHNOMATHEMATICS: COGNITIVE, ANTHROPOLOGICAL, HISTORIC AND SOCIO-CULTURAL BASES

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We discuss the concept of knowledge and the cognitive process backing the evolution of knowledge in the human species. This leads to a reflection about the meaning peace. In simple terms, peace is the capability of dealing with conflicts [which are unavoidable as a result of individual differences] without the resource to arrogance and to bigotry, which culminates in aggression and violent confrontation. A road to peace is the reformulation of education. A proposal of a new concept of curriculum is presented and there is a brief discussion of the Program Ethnomathematics as the realization of the proposal.

Keywords: Knowledge; Cognition; Curriculum; Ethnomathematics

El programa Etnomatemáticas: bases cognitivas, antropológicas, históricas y socioculturales

Discutimos el concepto de conocimiento y el proceso cognitivo de soporte a la evolución del conocimiento en la especie humana. Esto conduce a una reflexión sobre el significado de paz. En términos simples, la paz es la capacidad de lidiar con conflictos [que son inevitables como consecuencia de las diferencias individuales] sin el recurso a la arrogancia y fanatismo, que culmina en agresión y la confrontación violenta. Un camino hacia la paz es la reformulación de la educación. Se presenta una propuesta de un nuevo concepto de currículo y hay una breve discusión del Programa Etnomatemáticas como la realización de la propuesta.

Términos clave: Conocimiento; Cognición; Currículum; Etnomatemáticas

In the course of this paper, it will become clear that the Program Ethnomathematics and the Theory of Objectification are complementary

explanations for understanding the strategies developed by the human species and individual humans to deal with *reality*.

It is important to clarify, in this very beginning, my use of the concept of reality. I simply consider reality to be the complex of natural and supernatural phenomena and facts, physiological, sensorial, emotional and psychic reactions to the environment in the broad sense, social interaction, indeed everything, which is permanently changing.

The central question is how both each individual (from birth to death) and all the human species develop strategies to cope with the ample reality as considered above. The ensemble of the strategies is a complex system of knowledge and behavior.

A proposal for a research program for this central question is to focus on two apparently distinct subjects of research:

- ◆ each individual member of the species and,
- ◆ the human species.

Both are mutually inspiring and challenging research subjects, as it was much exemplified by the research programs of Jean Piaget, Lev Vygotsky, among others, show how much we learn from children behavior. The links with education are obvious. The research must necessarily be transcultural and transdisciplinary, and borrows methods of research in the sciences, in cognition, in mythology, in anthropology, in history, in sociology (politics, economics, in education) and in cultural studies in general.

THE PROGRAM ETHNOMATHEMATICS

The Program Ethnomathematics is a research program focused in the question of how the human species developed their means for surviving and for transcending reality. It relies on the analyses of the history of ideas and of the evolution of behavior and knowledge of the human species, in every natural and socio-cultural environment. Although the Program Ethnomathematics initially contemplated the history and philosophy of mathematics and has, as a consequence, the obvious pedagogical implications, its focus grew to contemplate the complex system of knowledge and behavior generated and organized by both each individual (from birth to death) and all the human species. Both, as the human species in general, develop strategies to cope with the ample reality as stated in the preamble. As it will become clear in this paper, ethnomathematics is not a final theory, and this is the reason for calling my proposal a research program.

From this very beginning, I consider very important to clarify that my concept of ethnomathematics is much more ambitious than the study of mathematical ideas and techniques recognized in different ethnic groups and in

artisanship and professional practices and even in different civilizations, as it is the main focus of ethnography and ethnology.

I understand mathematics as broad category which is an abstract construct originated in the cultures of the Mediterranean Basin and the Mesopotamic (Ancient Iraq) and Nile valley civilizations. We might say that academic (school) mathematics is the ethnomathematics of that region. This category of knowledge is sometimes referred as the Euclidean style and it is supported by *tertium-non-datur*, is insufficient and even inadequate as a strategy to deal with facts and phenomena of other different natural and socio-cultural environments. As we learn from eminent historian of mathematics Wu Wen Tsun, ancient mathematics in China had a different method of thinking and style of presentation of Greek mathematics (Wen-Tsun, 1986).

We recognize similar abstract constructs when we study the history of mathematics in Ancient India, in the Andean civilizations, in Sub-Sahara Africa, in Polynesia, indeed in every civilization in the world. There may be some similitude in the abstract constructs in different civilizations, but they are essentially distinct. We have to understand the intellectuals, the artisans, the professionals, the people, the invisible society in these regions, their myths and systems of value, their knowledge systems. All are in permanent change. We have also to consider the dynamics of the encounters of civilizations.

As it will be explained below, I use the prefix *ethno* in a much broader sense than ethnic and also *mathema* and *tics* in a different meaning than in the academic discipline Mathematics.

The Program Ethnomathematics is conceptually designed as a broad research program of the evolution of ideas, of practices and of knowledge in the human species in different cultural environments. Essentially, it implies an analysis of how groups of humans generated ways, styles, arts and techniques of doing and knowing, of learning and explaining, of dealing with situations and of solving problems of their natural and socio-cultural environment. I practiced an etymological abuse with the “free” appropriation of Greek roots: *techné* –*tics*– meaning ways, styles, arts and techniques; *mathema* for doing and knowing, for learning and explaining, for dealing with situations and solving problems; and *ethno*, as distinct and specific natural and socio-cultural environment. Thus, using these Greek roots, I synthesized as *tics* + *mathema* + *ethno* the way groups of humans generated ways, styles, arts and techniques of doing and knowing, of learning and explaining, of dealing with situations and of solving problems of their natural and socio-cultural environment. It is easy to understand how this conceptual etymological construction gave origin to the word *ethnomathematics*. Although the words ethnobotany, ethnomusicology, ethnolinguistic, ethnomethodology and other *ethno*+disciplines are used by anthropologists, by ethnographers and sociologists for research of specific disciplines in different ethnic and social contexts, they base their research on the views of an observer of other cultures, trying to find commonalities between the culture of the researcher

and of the researched. My appropriation of the prefix *ethno* is very different. The conceptual way I introduced *ethno+mathema+tics* recognizes specific cognitive strategies of a culture to deal with reality. For example, it does not make sense to address different ethnic groups asking questions such as “what is the meaning of a triangle?” or “how would you add 2 plus 3?” or “what is the color of this flower?” The categories triangle, 2 plus 3, color may be absolutely senseless in their culture. Very illustrative of this remark is the research on the *pirahã* culture in the Amazon Basin conducted by Daniell L. Everett. This research is related to the intriguing question of mutual influences of culture and cognition.¹ My appropriation of the concept of *mathema* as a philosophical category is fundamental. I claim that there are different ways of doing the equivalent of “mathematics” in different cultures. We might further explore my claim discussing the dispute of monism versus pluralism in logics. I will not discuss this in this paper.

The etymological abuse makes clear that to do research in the Program Ethnomathematics we must dialogue with ethnic group, with the intellectuals, the artisans, the professionals, the people, and the invisible society. A research methodology of the Program Ethnomathematics consists essentially of the steps:

- ◆ How do ad hoc practices and solution of problems develop into methods?
- ◆ How do methods develop into theories?
- ◆ How do theories develop into scientific invention?

I will not give examples of how this methodology is practiced. This can be seen in innumerable publications in the area (D'Ambrosio, 2017). But I move into theoretical reflections that support the Program Ethnomathematics.

FROM REALITY TO ACTION

Reality, in the broad sense I presented in the Preamble, informs individuals, who process the information and define strategies of actions, which are ad hoc solutions to situations and problems, with the objective of dealing and explaining the facts and phenomena of reality in the broad sense. The information is processed by the brain/mind complex, which is considered the most challenging research theme in all fields.

The main ideas in my theory are based in the scheme: Reality informs the individual that processes the information and defines strategies of action which affects reality, which once modified supplies new information for the individual that processes the new information and defines new strategies of action which again affects reality, which again informs the individual which again processes... and so on continuously (Figure 1).

¹ A synthesis of this research is in the book of Daniel L. Everett Don't sleep, there are snakes. Life and Language in the Amazonian Jungle. (Everett, 2009).

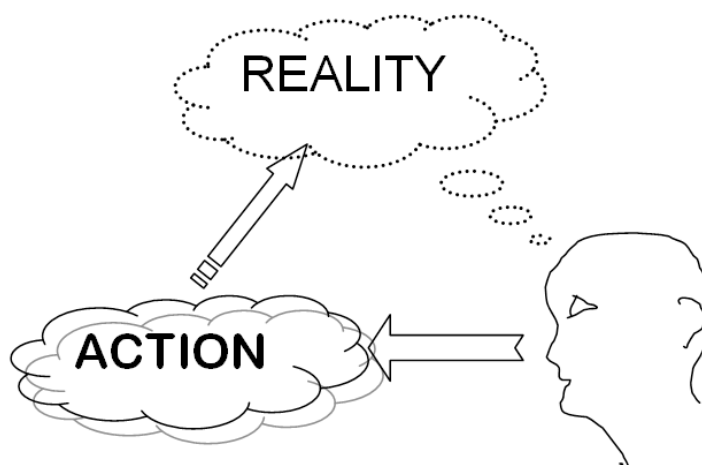


Figure 1. Problems selected for the study

This cycle is permanently performed by every individual, from birth to death. This is the reason why I call this the cycle of individual life.

The situation is very complicated, since individual A is not alone. Individual A coexist with another individual B. Individual are always different. Only in fiction there are clones. Each individual perform their own cycle of individual life.

They receive different information from reality (for example, one of them may be blind and the other sighted), hence they process the received information in a different way and, obviously, define different strategies of action. These strategies may be conflicting. There are no reasons for the strategies to be the same. Their sensorial perceptions and brain/minds are obviously different and each one processes information in a personal way.² In my view, this is the most critical issue in social relations, in particular in education.

The challenge to human relations is to deal with different strategies of action. In ways not yet well explained, the human species developed language, a special kind of communication which intervenes in dealing with conflicting actions. I will not attempt to reflect on the nature of language. This is a very difficult area of research and I refer to the book of Daniel L. Everett (2009).

A main focus of the Program Ethnomathematics is to understand how humans, both individuals and groups of individuals, developed throughout history and also nowadays, different strategies of action. The strategies of action normally resort to ways, styles, arts and techniques of doing and knowing, which rely on learning, explaining facts and phenomena, and dealing with new situations and problems, in specific natural and socio-cultural environments. This is a cumulative process developed by an individual and shared with other

² A good example illustrative of this situation is the movie *See no evil, hear no evil*, Director Arthur Hiller (1989).

individuals of a group with common ancestry, myths, values, language and many other factors of affinity. Communication is fundamental in this process. The affinities result in common knowledge, in compatible behavior of individuals and of a common set of values, and also a common language. These are the cultural traits of the group. The dynamics of encounters of individuals of different cultural traits enriches the entire process. This is intrinsic to the world-wide evolution of the species and to migratory fluxes. The migratory fluxes occurred with different objectives, such as looking for food and shelter, for mating partners, for land dispute and conquest, for mythological/sacred reasons, for commerce and many other factors.

The complex of strategies of action developed by groups of humans living in different natural and cultural environments, are basically the response to the *pulsion of survival* of the individual (nourishing) and of the species (mating), which is common to every living species, and to the *pulsion of transcendence*, that goes beyond survival, which is unique to the human species. The pulsion of survival (common to all living species) and the pulsion of transcendence (unique to the human species) are characteristic of the human species.³ Later in this paper I will discuss this.

In response to the pulsion of survival, humans develop, like every animal species, strategies to deal with nature in the most immediate environment, which supplies air, water, food, and with another individual necessary for mating and procreation (the other of different gender, male or female). This guarantees the continuation of the species. Gregariousness led to groups sharing space and time and to a society. In general, every animal species developed, to cope with the diversity of strategies, systems of communication, based on movements, sounds, gestures. But humans went further, developing language, a sophisticated system of communication, as mentioned above.

In response to the pulsion of transcendence, unique in the species *homo*, each individual develops the perception of past, present and future, and their linkage, organized as memories, and the explanations of facts and phenomena encountered in their natural and imaginary environment. These are shared, as discussed above, and constitute individual and collective memory and are organized as representations of the real. Memory naturally leads to attempts to explain the origins, which resulted in the creation of myths and mysteries and of divines, responsible for the origins. Knowing about the future is an urge that gives meaning to human action. No one better than the divines knows about the future. Humans developed arts and techniques of consulting the creators, the divines, about the future. These arts and techniques constitute the divinatory arts. Examples are astrology, the oracles, logic, the "I Ching", numerology and the sciences in general, through which we may know what will happen – before it happens. All divinatory arts are based on observing, comparing, classifying,

³ I use the word *pulsion* in the psychoanalytic sense, similar to *trieb* as used by Sigmund Freud.

ordering, measuring, quantifying, inferring, and the quintessence of mathematical ideas.

Representations of the real evolved as artifacts, instruments and decorative objects, and as mentifacts, such as systems of explanations of facts and phenomena. These explanations are organized as arts, techniques, theories, whereas artifacts are the elements of the material culture, mentifacts can be understood as the elements of the mental culture. Mentifacts include the symbols and codes of a culture.⁴

SYSTEM OF KNOWLEDGE

In every living species, the generation of knowledge and of behavior is individual. Knowledge and behavior interact, as if in a symbiotic relation. The human species developed a very sophisticated form of communication, which allows knowledge and behavior to be shared and compatible, as discussed above. Through encounters and communication, common knowledge and compatible behavior of a group develops into what is called culture. Values are associated with the way individual and groups behave as a result of their knowledge, and are implicit in the common knowledge and compatible behavior of the group. Hence, values are cultural.

Culture is transmitted both in space and time through encounters and communication. To develop values we need to understand the dynamics of this transmission. But culture, the same as life, is not static. It is in permanent change, through inter and intra-cultural evolution. Hence, culture is transformed and, as a consequence, values change.

In human history, there is an evolution of encounters, from walking to space travel, and of communication, from talking to internet. This evolution sets the scenario for some reflections on the dynamics of cultural transmission in the present and the possibilities for the future. This dynamics is affected by education. Values are a result of this dynamics.

We need a dramatic change in the foundation of our civilization. Social norms and values associated with the meaning of work and wealth, which are based on win/lose and scarcity/abundance aims, are unsustainable. We need an ethics, focusing on the shift from competition to collaboration, from human separation to human interconnectedness, from human dependence to human interdependence, from fear to love. This shift will be the most significant change in all of human history and the beginning of a journey in the direction of a planetary sustainable civilization.

⁴ I frequently use the terms artifacts and mentifacts. These words, together with sociofacts, were introduced by the biologist Julian Huxley (1887-1975) as the basis for a theory of culture. They are also used in cultural semiotics.

This can be facilitated and supported by the advances in communication and information technologies, which serve the purpose of connecting humanity. We are approaching a breakpoint in human history, with the possibility of creating a new civilization.

While this paper carries a message of hope for the future of mankind, we must point to the dangers facing nature, mankind in particular. There is a threat of extinction of civilization.

It is a fact that in the very short span of his presence in the planet, man became marveled to find himself as the focus of a process, but, at the same time, is threatened by extinction. Environmental decay, greed and violence are but a few indicators of the road to extinction.

The economic structure supporting current style of life is clearly unsustainable. Indicators of this are the inequity of living conditions, which manifests in increasing poverty, both internally in every country and among nations, the unrelated goals of production and consumption, causing unmanageable waste, and the fragility of the economy. Short sighted policies of the most powerful nations in adopting environmental protection measures, such as the Kyoto protocol, and of supporting peace moves, such as an anti-ballistic missile treaty, are indicators of irresponsibility in dealing with the state of the world and with the legacy of this generation.

Public services, inclusive education, health, transportation and energy, are increasingly in the hands of corporations. About 20 years ago I commented on protest groups like Greenpeace⁵, ATTAC (Association pour la taxation des transactions financières pour l'aide aux citoyens)⁶ and others non-governmental organizations, defy established governments. Today we have Anonymous⁷. The demonstrations in Hamburg in the occasion of the encounter of the G20 is also a good indicator of the call for changes in the model of civilization. There are even signs of the emergence of parallel governance. These actions groups and the reactions by the power structure generate violence which plagues the relations of states and nations, of communities and schools, and even families. Confrontation and violence, instead of dialogue, has been the option. Mounting violence is a no-end perspective.

The only possibility of escaping extinction of civilization is to achieve peace in its broadest meaning: inner peace, social peace, environmental peace and military peace.

What is peace? Putting it in the simplest terms, peace is the capability of dealing with conflicts—which are unavoidable as a result of individual differences—without the resource to arrogance and to bigotry, which culminates in aggression

⁵ <http://www.greenpeace.org/international/en/>

⁶ *Tout sur ATTAC*, Éditions mille et une nuits/Librairie Arthème Fayard, Paris, 2000. See <https://www.attac.org/en>

⁷ <http://anonofficial.com/>

and violent confrontation. The only road to peace is through dialogue, based on a global understanding of the essentiality of individuals, society and nature, the basic components of the phenomenon life, which I will discuss below.

THE PHENOMENON LIFE AND THE HUMAN SPECIES

The only road to peace is through dialogue, based on a global understanding of the phenomenon life, which implies the recognition of differences. This dialogue, usually undertaken in an intra-cultural scenario, must be not only inter-cultural, but indeed adopt a transcultural strategy. Transcultural dialogue is, basically, the attempt to understand the other, recognizing that the other does not have the basic understanding as oneself has. It crosses time and space.

It is interesting to observe how the concept of life evolved with the evolution of knowledge. I use the example of three encyclopedias.

In Isidore of Seville's (ca.560-636) on "Man and Monsters", we read:

Life, vita, is named because of vigor, or because it holds the power of being born and of increasing. Whence also trees are said to have life, because they spring up and grow (Share, 1964, p. 38).

Birth and death are the boundaries of life. But much later, in the Modern Era, the *Encyclopædia Britannica*, 1771, states

Life, is peculiarly used to denote the animated state of living creatures, or the time that the union of soul and body lasts (Britannica, 1771, p.6).

We see an explicit recognition of the duality of body and soul, or mind and matter. In current days, *The New Shorter Oxford English Dictionary on Historical Principles* explain, as the first meaning among many others, that

Life. The condition, quality, or fact of being a living organism; the condition that characterizes animals and plants (when alive) and distinguishes them from inanimate matter, being marked by a capacity for growth and development and by continued functional activity; the activities and phenomena by which this is manifested (Oxford, 1993, p. 1608).

In all these conceptualizations of life, the concern is with the individual and life is bounded, limited in time. We might say that life is a phenomenon capable of reproducing itself, capable of adapting to an environment and also capable of independent actions not decided by some exterior agent. Life is most generally carbon based, indeed a complex combination of commonly found atoms. In synthesis, the quintessence of life is its capacity of continuity, understood as survival of the individual and of the species, thanks to the interaction of an individual, of another individual and of nature. Each one acts upon the other and

the three are mutually dependent. The suppression of any of the three elements or of any of the three mutual interactions causes the end of the cycle of life.

There are evidences that life in the planet Earth dates back to about 4×10^9 years. Life is characterized by the capability of continuity through self-reproduction. About 10^9 years ago occurred sexual differentiation of more complex forms of life and are evidence of early forms of animal life about half a billion years ago. The early hominids appeared about 6 million years ago, maybe with the emergence of the *Orrorin tugenensis*, whose fossil was found in Kenya's Tugen Hills, considered, by inconclusive evidence, to probably be the first bipedal hominin species. Every once-a-while fossils are un-earthened and provide new elements for controversial theories of human evolution. The *Australopithecus*, which existed from 4 to 2 million years ago, evolved as *homo erectus*, migrated out of Africa about 2 million years ago, and spread throughout Eurasia and to other regions of the planet. In these regions they evolved, leading to, among others, the species *homo neanderthalensis*, which lived approximately from 400 000 to 40 000 years ago in Europe and Asia. This species adapted to colder environments and lived in shelters, mainly caves, made and wore clothing and controlled fire. They hunted large animals and developed tools and instruments. They buried the dead and made ornamental and symbolic objects. It is even possible that they practiced cults and developed myths. This is the emergence of symbolic thinking. The species *homo sapiens* evolved in Africa about 200 000. They gathered and hunted food and moved extensively to look for more favorable environments. Eventually they reached Europe and Asia and coexisted with *homo neanderthalensis* for at least 10 000 years and could have shared habitats in what must have been a complex relationship, involving competition and possibly some interbreeding. There is growing interest in learning more about Neanderthals. Particularly interesting are recent results about symbolic and ritualistic behavior of Neanderthals, which places the origins of Art and the emergence of myths at about the same time as the origins of early tools. The *Howiesons Poort* culture, that flourished about 60 000 BC in the Eastern Cape province in South Africa, is an example of lithic technology and the emergence of decorative arts, characteristic of early symbolic culture and even shows a protomarket as an exchange of gifts with symbolic meaning is. In other words, survival and transcendence have been together since earliest signs of intelligent behavior of our species, particularly through art.

In the human species, action manifests, basically, in two ways:

- ◆ actions which lead to survival of the individual and of the species, and the satisfaction of needs, common to all living beings, which are performed in the instant; this I call the pulsion of survival;
- ◆ actions which satisfy man's needs for explanations, for understanding, for prediction, for creating, in response to will, which lead to transcend the

instant and to search the past and probe into the future; this I call the pulsion of transcendence.

The species *homo* seem to be the only that developed a sense of past and of future, transcending the present. As stated above, human species are characterized by the association of the pulsions of survival, common to all living beings, and of transcendence, unique to the human species.

With the emergence of the species *homo*, tools, instruments, equipment, techniques came into playing a role in the relations between individual, other/society and nature.

In the encounter oneself recognizes the other, the different, recognizes the essentiality of the other, and recognizes the mutual dependence of oneself and the other, and nature as the common support of life. This leads to a primordial behavior, which implies continuity of life, in its broadest sense. This primordial behavior I call the ethics of diversity

- ◆ respect for the other with all the differences,
- ◆ solidarity with the other in the satisfaction of all her/his needs,
- ◆ collaboration with the other in preserving the common support for life.

This ethics precedes any notion of culture and is broader than subordination to a system of values. Indeed, it is transcultural.

I use a metaphor to further discuss the phenomenon life. In geometry, triangles are figures formed by six elements in solidarity: three vertices and three sides. If one of them is removed, the figure is not a triangle any more.

The first triangle showed in Figure 2, which I call the primeval triangle of a species, have as vertices an individual (self) of the species, nature as a whole and other individuals of the same species, constituting a group. Groups are present in every species as a consequence of gregariousness, which is intrinsic to the phenomenon life. The triangle represents the phenomenon life. Each individual relates to nature for survival (physiological principles of nourishment), to another individual for continuation of the species (physiological principles of mating) and the survival of the group is guaranteed by looking for and maintaining what is needed for the survival individuals of the group (principles of ecology). The violation of any of these principles disrupts life. This triangle is a representation of the pulsion of survival.

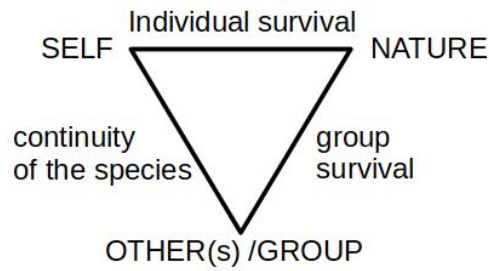


Figure 2. Primeval triangle of a species

In every species, the primeval triangle synthesizes the satisfaction of needs for the survival of the individual and of the species. I call this the pulsion of survival, intrinsic to every living species.

The human species has specificities. I consider an enhanced triangle of the human species (Figure 3), representing the intermediacies of the human species in the sides of the primeval triangle. These intermediacies are between an individual (self) and nature, which resulted in the invention of instruments and techniques to access the needed nourishment from nature; between an individual (self) with another individual, and consequently to the group, which goes beyond simple mating and develops language, as a sophisticate form of communication, codes of behavior and emotions; between groups and nature, which are the practice of collective labor and production. All these intermediacies are responsible for the emergence of civilization.

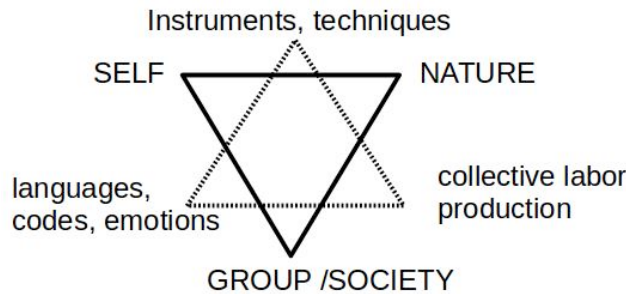


Figure 3. Enhanced triangle of the human species

This triangle marks the distinction of the human species from other animal species. The human species, in creating all these and other intermediacies, goes beyond, transcends the satisfaction of needs for survival. I call this the pulsion of transcendence, intrinsic to the human species. Thus, all the actions of the human species are a result of the pulsions of survival (common to all living species) and of the pulsion of transcendence (unique to the human species).

The basic intermediacies evolved into preferences and tastes, into power, into will and into the *tics* of *mathema*, into doing and knowing.

In the human species, every individual is subjected to needs and to will, proper to this individual. In general they are in conflict with needs and will of another individual. Regrettably the conflict may develop into confrontation. I call

humaneness the harmonious conciliation of needs and will of the individual and of the other individual.

THE ESSENCE OF POWER AND THE SOCIAL ORDER

The pulsion of survival generates the need for coping with the environment, the search for explanations and the curiosity of understanding. A consequence is the idealization of superior beings, many or unique, who are responsible for reality (creators), with unlimited knowledge, authority (omnipotent) and presence (omnipresent). To please or displease the superior beings imply reward or punishment, both in and after life. To be favored by the superior beings becomes a goal. Religion and religious practices, accompanied by art and systems of symbols, paves the way for complex societal organizations. To please or displease the favorites of the supreme beings can be equally rewarded or punished. While in the animal kingdom power is a strategy for survival of the individual and continuity of the species, in the human species it becomes associated with satisfying the will of superior beings.

The search for understanding, explaining and coping with this complex situation leads to systems of knowledge, which incorporate the belief in creation and in the cosmic and social order. Thus, myths become instruments of power.

The era that we call civilization started only around 10 000 years ago, with the emergence of agriculture and urbanization. This made it necessary the development of different forms of knowledge. Knowledge has been and continues to be employed for maintaining and improving the evolvement of different models of social organization which support different production systems.

With the impressive emergence of the civilizations of Antiquity, in different parts of the world, the encounters became strategies for claiming prevalence of one system over others.⁸ With the emergence of Christian and Islamic faiths, religious conversion became the main support of the prevalence. The great navigations, the colonial era, and the post-colonial globalizing expansionism, euphemistically labeled the free market era, all have been supported by principles and theories, coherently structured.

In an intriguing essay, Peter Raine sees globalization as revealing two sides:

Firstly the deleterious impact of technological and economic development on the Earth's living systems (i.e., the environmental crisis), and secondly the increasing demand of indigenous and autochthonous peoples to express their own unique claim to a coherent, intelligible, and equally valid worldview. These people not only wish to

⁸ It is common to refer to four great civilizations of Antiquity: Egypt, Mesopotamia, Greece and Rome. Indeed many civilizations were flourishing in the same epoch. Seventeen civilizations are listed by Melko (2001).

guard their own Earth, but also to guard it from the actions of people who belong to the predominant Western worldview. That technology, science, materialism, and even rationality may be rejected by some, comes as a surprise to many modern people, especially those who are wholly convinced that theirs is the only way to apprehend reality. (Raine, 2001, p. 5).

A model of rationalism provides this conviction. Identified with objectivity, its validity is frequently assured by theories subordinated to a decided logic and anchored in experimentation. On the other hand, traditions are based on experiences, which are often referred to as subjective knowledge. The major conflict occurring in modern thought is a seemingly irreconcilable feud between practitioners supported by experimentation and those supported by experience.

Experimentation, identified with science, is necessarily linear and ideologically loaded. The aim of experimentation is to consolidate accepted knowledge, and it implies a preponderance of the experimenter over the subject of experimentation. Experimentation is arrogant.

On the other hand, experience, identified with the traditions, comes as a mutual respect and interaction of the observer and the observed, and is necessarily non-linear. The observed reveals itself. Experience is humble.

The crux for a viable future is the capability of conciliating these two views, science and traditions. I do not agree with the option of “a third culture”, in the sense used by C.P. Snow in the revised edition of his classic (Snow, 1959). It is not a matter of opening communication between scientists and humanists, but rather of making both, scientists and humanists, aware of the totality of phenomena. To bridge the gap it is necessary to overcome the usual prejudice generated in the intracultural dialogue, which is impregnated by arrogance. But it is not enough to reach an inter-cultural dialogue. We must go even further, aiming at the transcultural dialogue. The eminent physicist Murray Gell-Mann says:

Unfortunately, there are people in the arts and humanities –conceivably, even some in the social sciences– who are proud of [knowing] very little about science and technology, or about mathematics. The opposite phenomenon is very rare. You may occasionally find a scientist who is ignorant of Shakespeare, but you will never find a scientist who is proud of being ignorant of Shakespeare. (Brockman, 1995, p. 22).

The key point is the meaning of knowing. Indeed, without much more than a proficiency in common English and some sensibility, everyone can follow Shakespeare's arguments. But it is hard to follow the arguments of scientists. Their language is more like a jargon. Claiming that it must be rigorous and precise, it is hermetic. Thus my reference to epistemological cages.

Some years ago, I have introduced a metaphor, the epistemological cages, as the habitat of disciplines. It is not possible to leave the cage. The advancement of knowledge and the search for new knowledge is limited to what is inside the cage, subordinated to the specific epistemology. As a figurative saying, it is not possible to see the color of the external painting of the cage.

Following this metaphor, I consider disciplines as “encaged” knowledge. Methods and results are specific to deal with well defined questions. The juxtaposition of epistemological cages is a metaphor for multidisciplines, metaphorically as neighbors. Opening a door of communication between the cages is the metaphor for interdisciplines, which is equivalent to inserting cages in a larger cage. This allows to consider objectives and methods common to both, as well as accepting accorded criteria of truth, rigor and precision, and normative specificities, such as systems of codes and language, and even a common jargon. It is similar to a larger cage, an “aviary”.

In these expansions, from disciplines to multidisciplines to interdisciplines, the metaphorical image is the same: inquiry is limited to what is inside, the methods are limited by the wires. The results tell nothing of what is going on outside.

The proposal of transdisciplinarity is the freedom to leave and return to the cages. It is not a proposal for abolishing the cages, but for abolishing the exclusivity of specific cage to face situations and problems. Transdisciplinarity is an open system of knowledge, of inquiry and of search. This implies a necessary to relax specific objectives and the supporting categories and criteria of validation. Precision and rigor are subjected to openness, coherence and respect. Inevitably, fuzziness prevails.

To popularize science is still regarded with disdain. But some scientists challenge the scientific establishment and try to reach a larger public. It is possible that the insistence of Galileo writing in Italian played a role in his process. When Newton wrote the accessible “Opticks” (1704), his theories were embraced by artists. Sigmund Freud and Albert Einstein became household names and quantum theory captured the imagination of every sector of the academia. Gödel’s ideas, once translated into common language, were immediately incorporated by mystical thinkers and social scientists. All these examples met with the arrogant disapproval of a very large part of the community of mathematicians and physicists, who insisted in the exclusivity of the epistemological cages.⁹

The internal conflict in the academic community continues. The renowned astrophysicist Halton Arp describes the attempts to publish a book in which he challenges current theories of the origin of the universe. In the book, Arp denounces the fact that scientific discoveries which challenge the truth of

⁹ Illustrative of this arrogance is the polemic raised by Alan Sokal hoax, which deflagrated the so-called “science wars” (Lingua Franca, 2000).

accepted knowledge, are rejected, and even ridiculed by the established academia (Arp, 1998).

The meaning of knowing has much to do with the meaning of “for all”, to which I referred in the caption of this paper. The key issue is the acceptance of non-privileged access to knowledge. This meets the barrier of the language inbuilt in the structured organization of knowledge, which mystifies basic ideas.

This leads to discussions about the most basic and comprehensive knowledge, that is worldview, which is backed by *mythos* and *logos*. *Mythos* is the substratum of worldviews, out of which we try to explain reality. *Logos* is the system of arguments which “explain” the *mythos*. The interplay of *mythos* and *logos* is the history of the human species. These concepts are essential in the thinking of the theologian Raimon Panikkar, who claims that “mythos and logos are two human modes of awareness, irreducible one to the other, but equally inseparable” (Panikkar, 1979, p. 100).

According to Raine (2001),

Myth is a whole; it cannot be reduced to its parts. Logos, is the realm of the intellect: it is the reasonable, all that is thought and spoken of. Logos is the domain of the rational, the reasonable, and the communicable. Logos originates from the mythos, yet if a myth is rationalized or pierced by reason it ceases to be mythos. However, if a myth is recognized by logos it then becomes part of the intellectual realm and a new myth emerges to replace it (p. 13).

Education, particularly science and mathematics education, must be radically changed to recognize this interplay, thus creating the conditions for a comprehensive view of the universe. I do not see as important what some people call “high quality science education”, measured by standardized tests, and claiming goals of quality borrowed from industrial production. I mean an overall education, asking for a worldview and finding a meaning for the human presence in the world. What is the meaning of the human being being human? This word game synthesizes the great illness of mankind: the dichotomy of human being (substantive) and being human (verb). The only way to eliminate this dichotomy is to revamp our educational curricula.

Great changes in education are now possible, thanks to splendid advances in the domain of communication and information theories and, what is even more impressive, by the emergence of artificial intelligence and automation.

These new fields of knowledge, which make possible the substitution of humans by all kinds of robots, have been conceived, designed and implemented by the big corporations, in order to consolidate perverse policies. Paradoxically, these same advances allow for bigger awareness of the worldwide situation. They offer enormous potential to find a way leading to a decent survival of our species.

BRINGING ALL THIS TO SCHOOLS

The ideal of a same school for all is a trend for a new social order in the entire world. Another concept of school requires a new concept of curriculum. The classical curriculum *trivium* of gramatics, rethoric and dialectics, which prevailed since the European Antiquity and continued through the Middle Ages, was gradually being replaced in Modern and in the Industrialized Ages. Contemporary Ages by the three R's *trivium* of Reading, Writing and Arithmetic. This was necessary to prepare new generations for the increasing urban population and for the new demands of labor and commerce. The new demographic scenario demanded proficiency in the common language and in common counting and measuring abilities. To carry on the demands of new styles of commerce, of new job opportunities and of the practical needs of daily life the dialects and home practices are insufficient for the new society. The three R's *trivium* were appropriate for that social reality.

After the Second World War, the end of colonialism and the creation of the United Nations were responsible for new international dialogues and planetary concerns. The amazing progress of science and technology serve the support for special agencies of the United Nations, such as UNESCO, World Health Organization, World Trade Organization and many others. All the specialized agencies respond to great challenges intrinsic to Globalization. The migratory flux, voluntary or forced, is increasing at an unpredicted rate. The amazing advances of technology, particularly in information and communication are amazing. All this scenario profoundly affects education. The traditional curriculum is insufficient to cope with the new reality. We need new thinking in education.

A few years ago, I proposed a concept of curriculum which I feel more appropriate for the world scenario and to prepare for citizenship in the present world (D'Ambrosio, 1999). My proposal is to organize schooling along three strands, which I call literacy, matheracy and technoracy. I introduced these three neologism for new concepts of education, which will be explained below.

Literacy is the critical capability of processing information, such as the use of written and spoken language, of signs and gestures, of codes and numbers. Clearly, reading has a new meaning today. We have to read a movie or a TV program. It is common to listen to a concert with a new reading of Chopin. Also, socially, the concept of literacy has gone through many changes. Nowadays, reading includes also the competency of numeracy, the interpretation of graphs and tables, and other ways of informing the individual. Reading even includes understanding the condensed language of codes. These competencies have much more to do with screens and buttons than with pencil and paper. There is no way to reverse this trend, just as there has been no successful censorship to prevent people from having access to books in the past 500 years. Getting information through the new media supersedes the use of pencil and paper and numeracy is

achieved with calculators. But, some mathematics educators will ask where mathematics goes if dealing with numbers is part of modern literacy.

Matheracy is the critical capability of inferring, proposing hypotheses, and drawing conclusions from data. It is a first step toward an intellectual posture, which is almost completely absent in our school systems. Regrettably, even conceding that problem solving, modeling, and projects can be seen in some mathematics classrooms, the main importance is usually given to numeracy, or the manipulation of numbers and operations. Matheracy is closer to the way mathematics was present both in classical Greece and in indigenous cultures and to my concept of *mathema* as discussed above in this paper. The concern was not with counting and measuring but with divination and philosophy. Matheracy, this deeper reflection about man and society, should not be restricted to the elite, as it has been in the past.

Technoracy is the critical familiarity with technology. Of course, the operative aspects of it are, in most cases, inaccessible to the lay individual. But their use and a discussion of the basic ideas behind technological devices, their possibilities and dangers, the morality supporting the use of technology, are essential issues to be raised among children at a very early age. History shows us that ethics and values are intimately related to technological progress.

Literacy, matheracy and technoracy together constitute what is essential for citizenship in a world moving swiftly toward a planetary civilization.

IN GUISE OF A CONCLUSION

In conceptualizing this proposal of a curriculum for the new era we are now entering, it was clear to me that mathematics as conceived in the current school systems is both insufficient and discriminatory to the majority of the population. In proposing matheracy the intention is to give a much broader dimension to mathematical thinking, stressing its value as an instrument for explaining, understanding and coping with reality in its broad sense. Matheracy is the main intellectual instrument for the critical view of the world.

A realization of this new concept of curriculum is the Program Ethnomathematics. The main purpose is to build a civilization that rejects inequity, arrogance, and bigotry. Education must give special attention to the redemption of peoples that have been for a long time subordinated and must give priority to the empowerment of the excluded sectors of societies.

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