New Fundamentals of Mathematics for Schools

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If we look at the educational system as a whole, Mathematics is domineering subject. Together with reading and writing, it constitutes the spine of a system aimed at providing equal opportunity for all and ate the same time to prepare the cadres for the advancement and betterment of the socio-economic and political framework of society. The so called "three r's" have dominated school scenery for decades. Is this to be maintained?

The emergence of computer will surely affect the scenery and in predicting education in the 1990's, a dominating role is reserved for information-processors equipment. Although crossing and influencing all the three r's, the use of computers will most directly affect Mathematics Education in its very nature. Indeed, it brings new looks into the nature of Mathematics itself. Also pedagogical action as conceptualized by D'Ambrosio (y), will be deeply affected, and the curriculum seen as the strategy for pedagogical action, will call for new components. Although this much is relevant to our discussions, we will move directly into what is more directly related to our concern. Our essential concert is to identify a few indicators of how much is the Mathematics contributing to societal goals. Obviously, we are talking of long-range effects and broad and global societal goals. As we have stressed in the last paragraph of (D'Ambrosio, 1979) Mathematics appears as a strategy to attain overall societal goals. It is not easy to define long range societal goals, which are so much immersed in the concept of progress and development themselves, but a few values are permanent in any model of global policy. The American models is what dominated by the democratic ethos within a welfare state, and growing, equally prevailing force, is the ecological ethos, is closely related to concerned about the primacy of our species and, what is of absolute relevance to us, "the international of holistic-thinking in science and culture" as Richard A. Falk (1986, p. 68) put it. This calls for imaginative new models of social, political and economic organization. This echoes the so-called DECLARATION OF VENICE when it is said that "The challenge of our time -the risk of destruction of our species, the impact of data processing, the implications of genetics, etc., throw a new light into the social responsibilities of the scientific community, both in the initiation and application of research." (UNESCO, 1986).

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Our responsibilities as educators in a democracy, go beyond reproducing past and current models. We are primarily concerned with building-up a future witch shall be, in many ways, better than the present. This is our drive. Question: how much does Mathematics Education have to do with it? Our answer is unequivocally: everything to do!

Mathematics is deeply rooted in our cultural systems, and as such as loaded with values. Although it is not sufficiently studied as yet, the analysis of ideological components in mathematical thought reveals a strong connection with a certain socio-economic model. These parallel the ideological components of education in general which have been sufficiently stressed be Apple (1979), Giroux (1981) and the proponents of critical theory. Together with some eminently conservative practices, such as Medicine when dealing with normality and Law for hierarchy, Mathematics sides up as promoting a certain model of power through knowledge. We could easily paraphrase Duncan Kennedy (1983) be saying that Mathematics teachers indoctrinate students to believe that people and institutions arrange themselves in hierarchies of power according to their mathematical ability. The "superiority" of high achievers in Mathematics among their peers is recognized by all, Mathematics ability is the mark of the genius. All together, critical approaches to cognition, to social structure, and to state's interdependency, i.e., to the global world arrangement, puts us in an urgent need to examine to role of Mathematics in our educational system from a fresh outlook. Issues such as environmental decay, individual privacy and security, overspread hunger and diseases, threat of nuclear war, just to mention a few, are new to the exercise of thinking the future.

Undeniably, the future is impregnated of science and technology -for good or evil! And yet undeniably Mathematics is in the root of science and technology. A few years ago, the weekly "The Economist" published a lengthy article entitled "You cannot be a 20th century citizen without mathematics". The responsibility of mathematics educators towards the future is a focal one and we need to understand our role in this very complex net of shared responsibilities. This is how we see the right framework to discuss a system to monitor the health and progress of Mathematics in schools.

We cannot avoid briefly reflecting upon the way policymakers will use the information gathered by the monitoring system. In this respect, there is a clear need for an educational effort towards the policymaker. Using a metaphor utilized by Israel Scheffler (1984), we will need to design a curriculum for policymakers rather than merely providing then data. The metaphor is rooted on the need for the policy and decision makers of an understanding of the processes of learning and of the awareness of the position of mathematics in the fullness of everyday life, with its complexity of human activities, experiences, purposes and needs and consequential tensions and creativity. This calls for a broader understanding of the nature of our discipline itself and its position in the full range of human knowledge. As Scheffker puts it "the policymaker needs to be multilingual, to learn to speak and learn various disciplines dialects, and to employ them co-jointly in understanding the problems" (1984, p. 154). Is this less true for the mathematics educator himself?

Several issues are to be considered in planning a monitoring system. The fundamental one refers to the audience. We prefer to shift the issue to a mor general one which refers to accountability of the school system. Of course, a monitoring system will be used by state and local policymakers responsible for managing the educational system. On the other hand, the fact that these policymakers respond to public demands, is the main feature of a representative democracy. This is clearly evidenced by the tax system which prevails in financing American education. Hence, although primarily designed to be available to state and local policy makers, the monitoring system must be accessible to the entire population and must address the issues which are in the day-by-day concern of parents and pupils as well. As J. Myron Atkin, when discussing the improvement of Science Teaching in special issues of *Daedalus* devoted to scientific literacy puts it, "Most people want something practical, or at the very least, recognizable" (1983, p. 178). Hence, we have to deal with the value of an accessibility of our data. These data must be available to those solitarily responsible for decisions, i.e., policy makers plus their constituents, and must carry a pedagogical component. They must be instructionally designed, in a certain sense. Explanation, interpretation, critique of the results must go together with the information provided by the monitoring system itself. This is surely to be biased by monitoring system itself, and we can hardly see any other way to avoid this. After all, Mathematics Education is impregnated of values, as we have discussed in (D'Ambrosio, 1985). We will return to this later on.

We cannot disregard either the internal composition of the school itself, i.e., the relation between teachers, teachers and principals, principals and supervisors, and so on. Summing up, we have to deal with all the forces playing a role in the school system. This is highly complex net of influences shaping Mathematics Education. This was discussed by Paulus M. Ferdes in ICME-5, in the case of a highly traditional society as in Mozambique, and it has been evidenced in literature, basically in the process moved against Gustave Flaubert following the publication of "Madame Bovary" and mor recently in Giovanni Lada's "Padre Padrone". An interesting approach to the expectations surrounding education can be found in the work of Teresa Amabile (1983). These expectations and interrelationships of the several actors in the educational stage are fundamental components to monitor the entire play.

Thus, an efficient monitoring system has to take into account the expectations of all those involved. These expectations range from an extreme of effectiveness and the enhancement of creativity, to the other extreme of pure utilitarianism. Of course, these are not dichotomic. Both respond to a particular view of society as a whole. This kind of dichotomy is clearly discussed by Plato in Book VII of the Republic. The comments by (Marrou,, p. 73). are rewarding. It is undeniable that more or less emphasis in one aspect or the other is a political decision, closely related to overall societal goals. Is *The Paideia Proposal* more akin to American ideals than the "Cack-to-Basics" movement? Or both aim to the same model of society?

If the first, i.e., *The Paideia Proposal*, is chosen then the attitude towards Mathematics Education will reflect the remark that "All students study Mathematics till the twelve years of basic schooling. ... Mathematics is central to the manipulation and the innovation of information. Mathematics illiterates will be left behind. In addition, mathematical reasoning is one of the most human things that human beings do." (Adler, 1984, p. 84). How well can we monitor such a Comenian approach as compared with the "answer oriented" Mathematics

Education which prevails nowadays, and which Garth Boomer (1986), with evidence drawn from (Romberg, 1984), has properly called "Catechistic" teaching?

The basic issue remains open. Should Mathematics Education move into a creativity oriented, hence basically open, curriculum which is very difficult to evaluate in short term, or should Mathematics Education stick to the performance oriented traditional model. Several examples of open, creativity oriented programs have been proposed throughout history. Their assessment is practically impossible. Impact evaluation, as it has been sometimes called, is in an unsatisfactory stage as yet. Affective components are possibly the only indicators on which one can rely in this case. Monitoring must then be directed to small group behavior, changing from quantitative to qualitative instruments. This will have immediate implications for the curriculum. Clearly, monitoring systems act in a dual target mode. Although aimed ate policy and decision makers, its reflection on curriculum and classroom managements is unavoidable. Every teacher who is aware of the evaluation scheme will be deeply affected in its practice by this scheme. No way, and no reason for keeping the monitoring system "secret", hence the entire educational system is affected by the theoretical framework, upon which the monitoring system reposes. As a consequence, the monitoring system itself deeply affects the behavior of teachers. Hence, the monitoring system will have also the effect of influencing the educational systems.

Let us concentrate on the main questions we want to address in the monitoring system. The questions which must be raised and which will give us indicators of the health of the of the educational system may be grouped according to what may be looked upon as reasons to teach Mathematics with such intensity in the school system.

Among the several reasons which have been identified throughout the History of Education, we distinguish as the main ones:

1. Utilitarian.
2. Formative.
3. Cultural and
4. Esthetical.

We have no hesitation in saying that all these four reasons are equally valid, but there has been a growing unbalance in the last hundred years, clearly favoriting the first one, i.e., an utilitarian overemphasis.

In the last decades, an utilitarian emphasis has prevailed. This has been a mistake, and the mistaken character of a strongly utilitarian oriented Mathematics Education is reinforced by the appearance of calculators and computers. A traditional skills-oriented Mathematics Education is indeed absolute, inefficient. On the other hand, utilitarianism pays lip service to a new emphasis on applications to real world problems. Again, an authentic approach to real world problems must go into a different direction. There is no authenticity in the so-called "problem solving" situations stressed in the beginning of this decade. Even in its broader conception, as for example the one given in NCTM Agenda for Action (NCTM,), emphasis is laid upon given problems, presented in a formulated, already codified, mode. "Real" situations were indeed simulated situations, and although there was and there is an appeal to deal with "really real" situations, this cannot get into classrooms unless attitude towards Mathematics change.

More than everything else, this is the result of epistemological barrier. Curricular dynamics is not present in the classroom. Instead, Mathematics curriculum is decided in a strongly conservative way, relying on topics which have reached their final form, so to say Theories which have attained the stage of "normality" is the Kuhnian terminology. This is superbly described by Philip Kitcher (1984, p. 54): "the experts demonstrate their expertise by producing verifiable solution to problems which baffle us, that they produce plausible arguments against our contentions (arguments whose plans are too well hidden for us to detect), and that they offer convincing psychological explanations of our mistake". This appears in the context of Kitcher's argument against mathematics apriorism. We see that the underlying epistemology in Mathematics Education practice is aprioristic, while a Bacherladian approach has been absolutely ignored in education, particularly in Mathematics Education. Clearly, when Bachelard says that "L'état logique est un état simple et même simpliste" (Bachelard, 1981, p. 27) and that this state cannot serve as proof in the case of a psychological reality, he opens up a new direction for an approach centered in the psycho-emotional complexity of the student, rather than in the transmissible techniques, which a teacher tries to convey to his pupil. Indeed, he returns to William James and refers to him. Regrettably, James became marginal in Mathematics Education, the same as Bachelard's epistemology. The dominant trends in Philosophy of Mathematics tend to mask the fact that Mathematics is closely related to reality and to the individual perception of it. Reality informs the individual through a mechanism which we have insisted in calling *sensual* rather than *sensorial* in (D'Ambrosio, 1981), precisely to stress the importance of the psycho-emotional component. The key issue in problem-solving, which appears when we address ourselves a question such as "How well have the students in our state learned to solve complex problems?" may indeed be misleading question, and in order to monitor it we may have to distort the entire attitude in the classroom. Complex-problems are related to a new consciousness state, which William James puts clearly when saying that the state of consciousness in which we recognize an object is a new one as compared with the state of consciousness in which we have known the object. This reflects what have called sensual impact of reality upon the individual. Regrettably, Mathematics Education has tended to suppress the emotional of individual perception of reality.

The alternative approach to problem-solving call for effective immersion of children in global practices. Evaluation and the concept of exam takes then new dimensions. Problem-solving is indeed viewed in a much broader way, which combine modelling processes and creativity-training programs. Evaluation becomes than a qualitative issue rather than a quantitative one, an affective oriented search rather than a performance oriented one. The monitoring system must take into account some new indicators.

The issue of which indicators we may use in a qualitative, affective oriented evaluation system, is a fundamental one when we shift from traditional problem-solving to a modelling approach. A very imaginative proposal is implicit in the analysis of detective's behavior by

Umberto Eco and Thomas A. Sebeok (1983), when they add abductive reasoning to general considerations of reasoning processes. While discussions about problem-solving focuses on inductive-deductive modes of thinking, abduction, which may be conceptualized as a conjecture about reality which needs to be validated through testing, seems to be the basic component to deal with a real situation. According to Charles S. Pearce, abduction comes, together with induction and deduction, as an essential mode of thinking in the cognitive process. Although much has evolved in the understanding of the mind since William James and Charles S. Pierce, their approach to reasoning seems to be quite suitable to our understanding of mind-body processes.

Particularly appealing for renewed Mathematical Education is the evidence gathered by the proposer of a new vision of the cultural phenomenon which derives from socio-biology. Charles J. Lumsden and Edward O. Wilson try to understand the phenomenon of culture through a sequence of components which they call learning, imitation, teaching and reification. All but reification appear in several species. *Reification*, i.e., "the mental, activity in which hazily perceived and relatively intangible phenomena, such as complex arrays of objects or activities, are given a factitiously concrete form, simplified, and labeled with word or other symbols." (1981, p. 381] is characteristic to human beings.

Putting all together, we see that both Lumsden and Wilson, and much before them Pierce, see codification processes acquired through psychological mechanisms which go contrary to the linear structure which characterizes and underlies Mathematics Education practices. The codes are acquired through a verificative process, and then "stored" for further use in different situations. Among these codes is Mathematics. In fact, both suggest that the best way is a mere immersion of children into an environment where mathematical challenge comes naturally. In the same direction points out the work of Teresa Amabile, and also the psycho-pedagogical framework implicit in the LOGO proposal (Papert, 1980). This does not differ from the message given in "The Education of Henry Adams" (1983), and is also in the root of Dewey's pedagogical thought.

Trying to bring these considerations to the practice of Mathematics in schools, emphasis should be shifted to "really real" situations. Projects of a global nature, such as for example the building of a cabin, or mapping your town or assessing the water consumption of your community, provide situations which will require modelling and problem posing. Problem solving occurs as a consequence and then acquire meaning and its solution makes sense. A methodology which can be traced back to the project FOXFIRE 6 (1980) , as particularly seen in FOXFIRE 6 takes into account the child's own environment and gets started with what we may call "fact finding", in the sense of gathering information about a situation, then proceeding through modelling procedures, and finally ending a step further, on what might be called "realization", i.e., the transformation of the result into action or objects. This is based in the cycle reality -individual-action-reality, discussed in (D'Ambrosio, 1985).

This is unmistakably an open, activities oriented, approach to Mathematics Education, drawing much on the environment and consequently reflecting a priori knowledge. This leads to what we have labelled *ethnomathematics* ethnomathematics and which restores Mathematics as natural, somewhat spontaneous, practice. Although research on the influence of a priori ideas on the experimental approach in Science Education, mainly by the Piagetian school (Marmeche, Meheut, Sêré, and Barais, 1985) are frequent, in Mathematics Education efforts to identify ethnomathematical practices and recognize them as valuable background is relatively recent, and the advantages of building-up on the transition, as a powerful learning factor, is yet undiscovered.

From these considerations we pass to another set of issues which refer to difference in exposure to Mathematics by race, by social classes, by sex and how these differences reflect in the level of performance, attitudes, enrollment, and use of Mathematics.

Much emphasis has been put in the last two decades on these issues. Indeed, evidence has been gathered on the deprivation on the Mathematics achievement of blacks, of native Americans and other groups. Explanation has been sought, some leading to hints of sex or race natural inability to perform mathematically well, clearly rejected by all the sectors involved, and other explanations, strongly point to a social structure intentionally aiming at depriving women and certain ethnic and cultural groups of a full Mathematics Education. Of course, these intentions would fit into a model of male domination in a society whose hierarchy puts in leading and deciding position those with a better mathematical background. This is the prevailing position in every school system, and it is aimed at fiving the same Mathematics for all, assuming *first* that all will be able to absorb equally well this form of knowledge, which seems to be correct to the best of our understanding of learning-teaching dynamics, and *second* that this knowledge in this case Mathematics, fits into a mind structure which has Mathematics blue-printed in it. This is Kantian apriorism which has prevailed in the philosophy of Mathematics and has its reflection in totality of education.

New approaches to the nature of mathematical knowledge, as for example in (Kitcher,) and the growing attention being given to ethnomathematics, open a new and broad area of research on what may be called an anthropological approach to Mathematics, loaded with constructions of psycho-emotional and cultural issues. Then a form of Mathematics and parts of Mathematics which draw upon psycho-emotional and cultural motivation will naturally produce differences in receptivity by women, blacks, poor, etc., independently of the level of exposure. Explaining better: certain chapters of Mathematics have more appeal to women than others, others are more attractive to middle class, while protestant teen-age boys, and so on. What is undesirable, and would be avoided , is the valorization, in the school systems, of one kind of Mathematics over others. This is how ethnomathematics comes int the picture. In this context, the problem implicit when we ask about some Children receiving more or different exposure to content than others as a consequence of race, of social classes, of sex, is a false problem. The problem instead resides in over valuing one kind of Mathematics over others. Explicitly, by bringing into the classroom Mathematics which are closely related to activities mor appealing to young girls (such as house caring), the performance of these girls should improve relatively to their performance in bringing up questions which are related to typical boys activities. The same happens when drawing upon cultural issues, and some aspects of Mathematics which touches racial or religious background of children, for example. Much research is needed in understanding different reaction of children to these issues. Research is not very numerous as yet because of a mistaken trend towards the same Mathematics for all has prevailed in the last decades. The evidence we have pints out in the direction of girls doing better some kind of Mathematics than boys, blacks doing better than whites in some topics, and so on. Most probably, these differences are due to socio-cultural back-ground, although it is not excluded a genotypical influence. As much ''taboo'' as this subject may be, research in this area, such as the one carried on by Benbow and Stanley (1983), must be taken into account. In any case, the key issues are then to provide multiplicity of directions and diversified curricula to best suit different ''psycho-emotional'' and cultural patterns of children. Very much in the time of Howard Gardner's project, this multiplicity and diversity of mathematical experiences leads to curricula based on situations, following the general approach implicit in the works of Teresa Amabile and in creativity enhancing projects.

Again, we return to the modelling of real situations as the most adequate method to deal with such diversities.

Naturally, this implies the recognition of values in Mathematics Education which are not in a lesser standing than the utilitarian one. Indeed, in many cases the cultural and esthetical values, which imply the formative one, are even mor important. The utilitarian value, which has become prevalent in the last hundred or so years. Had been left, throughout history, to other domains of education. As we have discussed it in both (D'Ambrosio, 1979), and (D'Ambrosio, 1980), utilitarian views of Mathematics have existed in parallel with academic Mathematics, within a different track, until the changes which resulted from the great social and political new directions of last century. It is clear that the unbalance between the utilitarianism and other values, which has occurred in the last hundred years, has caused a dehumanization of science, technology and society as a whole. It is about time that we restore the humanistic focus to general education, to education for all, and hence to Mathematics for all.

Consequently, the quality of the Mathematics curriculum, be it considered with respect to sex, race, social classes or in an international comparison with the curriculum in other countries, must be faced in a different way.

Quality is assessed no merely by performance attitudes, enrollment, and even less by analysis of the content component of curriculum in all the three levels it is usually considered (intended, implemented, attained). Not only the analysis of the curriculum leads to false evaluations of the system, considered in the broader way we have been suggesting but it masks components of social injustice and biases towards several forms of discrimination, such as by social classes, by sex and by race.

In advocating the recognition of the ethnomathematical focus on the curriculum, we are implicitly recognizing Mathematics as a system of codification which allows describing, dealing, understanding, and managing reality. This is attached to a broad concept of what is knowledge vis-à-vis reality (D'Ambrosio, 1986a) (D'Ambrosio, 1986b). These codes go through basically two distinct processes: one derived from family and peer-group and whose institutionalization is loose and as yet no clearly understood. They belong close to the domain of anthropologists and have recently entered into the consideration of school systems. As yet there has been a resistance to look into these issues in the US school systems. These ethnomathematics -of course there are numerous ethnomathematics- are close to what

B. Bernstein (1971) calls the "restricted code" as contrasting with the "elaborated code" when dealing with language, or what Ivan Illitch (1982) calls " vernacular" language or "vernacular" universe.

A few characteristics of ethnomathematics should be stressed:

1. It is limited in techniques since it draws on narrow resources. On the other hand, its creative component is high, since it is unbound to formal rules obeying criteria unrelated to the situation.

2. It is particularistic since it is context bound, although it is broader than *ad hoc* knowledge, contrary to the universalistic character of Mathematics, which ideally claims and aims to be context-free.

3. It operates through metaphors and system of symbols which are psycho-emotionally related, while Mathematics operates with symbols which are condensed in a rational way.

Of course , this leads to an hierarchization of transmission of knowledge and to the fundamental issue of legitimation of knowledge. While ethnomathematics draws much of its validity on how does this work in this situation or how does this please me and fits my overall view of the world (i.e., it is value bound), Mathematics draws its authority on a sequential hierarchization starting with authority of written and printed word, reaching finally the authority of rational thought. This rationalistic goal leaves in its way, in its building up, values which are rooted in the cultural context to which ethnomathematics is a natural codification. To face Mathematics Education in a way that it embodies the child's value and culture, i.e., his/her ethnomathematics, seems to be a desirable road to a more humanistic version of rationalism.

The step from ethnomathematics to Mathematics can be seen similarly as the step from oral to written language. Written language (reading and writing) builds up a knowledge of oral expression already possessed by the child, and the introduction of written language should no suppress oral language. To understand and respect ethnomathematical practices opens up a vast potential for sense of inquiring, recognition of specific parameters and feelings for global equilibrium of nature. Yet, in the school systems (in all levels of scholarity and even in professional life), these ethnomathematical practices are disvalued, sometimes leading to humiliation, and in most cases considered irrelevant for mathematical knowledge.

A few lines above we have referred to "in all levels of scholarity and even in professional life". Let us clarify this , by extending our concepts of ethnomathematics to higher levels of knowledge such as physics, engineering, biology and so on. People like Paul Dirac, when introducing the "delta function", can be identified as an ethnomathematical, and the calculus practiced by most engineers, physicists and biologists, fits into what we may call *ethnocalculus*. Syslvanus Thompson, when writing his *Calculus made easy*, in 1910, was indeed putting ethnomathematics into print. The examples at this level could be multiplied. Regrettably, at children level this form of knowledge does not have enough strength to be noticeable to the pint of being in print. The school systems, which are essentially centered in the curriculum and in the performance to achieve it, eliminate ethnomathematics, which do not even get into being recognized. Recent work by T. Carraher, D. Carraher, A Schilieman, D. Lacey, J. Lave, and others are putting ethnomathematics into print.

Let us finally address ourselves the difficulty of building u a monitoring system which will be able to tell about the health of the system facing Mathematics Education in its cultural, esthetical and formative values and for which the utilitarian value is focused as than inability for which "really real" situations.

Cultural, esthetical and formative aspects of education can hardly be assessed. Respectful and dignifying vision of one's own being (a major issue in cultural aspects) cannot be measured directly, and esthetical values are hardly weighed. The same with the formative. Probably, the only parameters which will be possible to introduce in a monitoring system will relate to enrollment and possibly to classroom affective attitude.

With respect to the utilitarian values, which we see best achieved through global projects, schemes assessing participation, evolvement and reporting should be devised.

All that has been stressed as possible component of a monitoring systems depart substantially from current evaluation practices and reflect our inclination towards a total elimination of exams, tests and similar practices in the school systems.

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