given good results in knowledge transfer to Africa if they had been planned and supported with a long-term view and with the combined efforts of the government, industry and universities.9

Conclusion

SO is a work instrument which can help SD in Southern countries provided that the technology transfer is based on a sincere and unprejudiced North-South partnership because SD problems concern the whole world particularly as concerns the environment and the management and conservation of natural resources. In such a cooperation, it is capital for scientists and technicians of the South to be able to put into practice in the field the know-how acquired through training programmes.

In the context of the North-South cooperation, SO is intrinsically the most appropriate technology for arriving at SD in the southern countries. SO associates a technology perfected in developed countries with the means needed to interpret and valorise images of the natural resources of the planet. If the developed countries master the science & technology, the countries of the South possess the knowledge of their natural resources, over which they intend to exercise their sovereign rights. It is the common interest that should prevail in the negotiations on projects of SO application as a practice of information in the service of SD. For this is nothing more than an extension of the basic human rights. In the words of R. Lesgard "The future of humanity is not in a flight into space. It is more than ever on the earth, for the entire planet should be our common home and technosciences should contribute to form it and to respect it" 10

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A Paradigm Shift in Mathematics Education in the service of Sustainable Development

According to the Newtonian doctrine, "Time" is absolute, true and mathematical. It flows equally without relation to anything external. However, it seems that the time arrow while floating along the early years of the third millennium, is enchanted with the multidimensional systemic phenomenon of globalization which is compressing time and space, and transferring the whole world into a "global village" dotted with unprecedented advances. This time-space phenomenon is impacting almost every aspect of the life of individuals and societies. Hence, current literature, conferences and meetings reflect a universal enthusiasm calling for radical shifts in the content and conduct of education to allow all world citizens to successfully face up to globalization.1

Within this context and reacting to the swirl of changes which have taken place in the last decades of the 20th century in mathematics education, it is necessary to address the need to shift the culture of mathematics teaching and learning to suit the new modes of development and the reform features of globalization, focusing on four aspects:

- The concept of globalization
- Questions raised about mathematics education
- Examples of changes in mathematics education
- Guidelines towards a paradigm shift

Globalization

Globalization has been defined as "the increasing flow across borders and boundaries —whether national, economic, cultural, technological, or institutional— of people, goods, services, ideas, information, images and values".2 This is a big concept with loose definitions, sweeping generalizations and mostly with little accuracy. For present purposes it can be described, not defined, as a set of extended inter-relations all over the world in the fields of economy, culture, politics and civil societies.3

There is an interchange and two-way influence between globalization and advances in research and development. The traditional criterion for

development in terms of “Gross Domestic Product – GDP” and/or “Gross National Product – GNP” is about to be replaced by the “National Information Reserve – NIR”. For in an age where progress is gauged by the quality of persons - and not the quantity of their products - education, intellect and skills have displaced the old idols of the Industrial Age. In Math and Science education, accommodating globalization entails: bridging the technology and knowledge gaps between industrialized and developing countries as well as addressing the impact of market principles and the changing role of the state on education and their bearing on the planning and management of education. This cannot be achieved without the preservation of variety and richness of world heritage in a world becoming more and more homogenous.

In fact, in many of the industrialized countries, emphasis is laid – as a national priority – on the importance of technological literacy of the citizens (meaning computer skills and the ability to use computers and other information technology (IT) to improve learning, productivity, and performance) giving rise to a new terminology: “Smart Schools” or technology-rich schools, that we now have at the summit of educational systems. Thus, striving for excellence, where mathematics is a pre-requisite, is a major factor in the preparation of “smart” competitors equipped with the main tools of cognition for research and development. Consequently, it is economically and socially important to produce “numerate” citizens, high order problem-solvers, scientists and engineers.

This could be a day-dream if the mathematical foundations for these skills and disciplines are not laid at the appropriate time and at the relevant placement of the learners.

One of the major commitments of the World Conference on Science (Budapest, 1999), is the consideration of the current process of globalization and the strategic role of scientific and technological knowledge within it, as well as the new relationship between mathematics/science and society in coping with pressing global problems such as: poverty, environmental degradation, food and water security. The conditions for the production and sharing of scientific knowledge are themselves changing as a consequence of increasing intensity of communication, growing: interface between disciplines and tighter interaction between science and technology, universities and industry, laboratories and factories. Moreover, more diversified methods of teaching are crucial to the evolving educational system and hence, increasingly, formal education must be complemented through non formal channels.

Raised questions
The field of mathematics education has been and is still open to many research questions, such as:
1. Is the mathematics we teach the same as the mathematics used in everyday life?
2. Is mathematics becoming a subject at risk? What are the devils menacing the teaching culture in the mathematics classroom?
3. Can we teach – and is it proper to teach – mathematics as an experimental science rather than as “rhetoric verbatim”?  
4. What are the mathematical skills and the underlying know-what and know-how considered essential for the new development of globalization?
5. How are curricula and evaluation affected by the shift from objectives and outcomes to standards and benchmarks? And how should teaching be adapted to constructivism and interactive innovations?

Such questions and others have been dealt with in some research projects and doctoral dissertations and research on some aspects of mathematics education, at the global level has been done in a certain number of universities across the world. Paradigmatic shifts for reform ought to be research-based and critically guided. Within this context, countries should aim to establish high-quality scientific institutions capable of offering research and training facilities in areas of special interest. In the new framework of increased globalization and international networking, universities are responsible for providing students with the capacity to deal with global issues as well as flexible and up-to-date knowledge. In order to achieve this, closer dialogue between donors and recipients of science and technology funding is called for.

Examples of shifts for reform
The following are a few examples of indigenous shifts, rather than mere changes through re-organization of the same content as a result of addition or deletion of the traditional topics and practices:

A perspective from China
- Introducing useful mathematics to be learnt at the masters level so as to: acquire analytical skills, interpret computer-controlled processes, deal with real life applications such as cost, profit, forecast, risk evaluation, optimization, ecological systems etc.
- Emphasizing active learning such that the learners assimilate the new knowledge through construction of their own meanings and reconstruction of their cognitive structure.

US standards
- Following guiding principles, ten standards have been focused on for thinking about and doing mathematics. Five standards are concerned with the “Know What” or what is called ‘hard skills’. The other five are concerned with the
Paradigm Shift in Mathematics Education

"know how" or what is called 'soft skills'.

• Hard skills deal with: number and operation, patterns, functions and algebra, geometry and spatial sense, measurement, data analysis, statistics and probability

• Soft skills deal with: Problem solving, reasoning, communication, connections and representation

Victoria (Australia) Curriculum and Standards Framework (CSF)8

• This framework is adapted from the Australian nation-wide policy on mathematics education. It provides an outline and leaves the responsibility to schools for detailed development and delivery. It also places a clear emphasis on sensible use of technology, which is considered a valuable resource for learning mathematics

• Content is concerned with six strands: space, number, measurements, chance and data; algebra, mathematical tools and procedures.

• Learning outcomes and competencies are specified with time frames at each level of teaching – learning activities of the six content strands and sub-strands.

A South African Approach9

An outcome based approach was viewed by South Africa as a vehicle to ensure that learners would be prepared for life in a global society and understand the world they live in. The following cross-curriculum outcomes were identified:

• Identifying and solving problems in which responses show responsible decision-making based on critical and creative thinking

• Working effectively with others; communicating effectively, using visual and/or language skills in modes of oral/written persuasion organizing

• Collecting, analyzing, organizing and critically evaluating information and managing oneself and one's activities responsibly and effectively

• Using science and technology effectively/critically, showing responsibility towards the environment and demonstrating an understanding of the world as a set of related systems

• Using data from various situations to make intelligent and non-biased judgments and knowing how information is processed

• Analyzing natural forms, cultural products as representations of shape, space and time and acquiring experience with shape and space in one, two and three dimensions

• Making sense of aesthetic forms, relationships and processes from a variety of mathematical situations and using logical processes to formulate, test and justify conjectures.

A view from the Egyptian ECME10

The Egyptian Council of Mathematics Education (ECME), an NGO aiming to promote mathematics teaching and learning came up with some appropriate recommendations based on research papers and studies presented at its conferences, such as:

• Help the learners to see mathematics as a human living and desirable activity in which thought interacts with the tokens of number, symbol, pattern, shape and model so as to deepen cognitive understanding and competent skills

• Construct curricula systematically around parent mathematical concepts

• Decrease of traditional geometric practices and mechanical arithmetic and algebraic operations such as operations on: ordinary fractions, algebraic fractions, logarithmic tables, determinants ... different formulae of equations of straight line and circle, memorizing statements of theorems, giving pseudo proofs to plane and solid theorems, corollaries and problems

• Make room for new concepts and contemporary topics (i.e. discrete maths, probability, topology, chaotic phenomena ...)

• Add application units by the end of each grade at each stage encompassing the use of what has been taught in that grade or stage.

• Do not insist on technical terms in the early grades: begin with the simple language of children

• Functionallize the maths content in technical education, using visual and experimental mathematics in technical contexts

• Adapt methods of teaching to individual situations, using constructive learning theories.

• Raise levels of aspiration to meet international standards and national ambitions

• Give more attention to the role of research as a solid road to real and sustainable reform

Towards a Paradigm Shift

The following exemplifies two dimensional guidelines.11

Guiding Principles

• Every child is apt to learn mathematics and every learner is eligible to reach a mastery-level. Hence, mathematics should be for all

• New theories of learning indicate multi-intelligence, some of them are latent. Hence, differentiation in content and delivery systems are needed so as to plan for multi-tracks which awaken appropriate potentiality and ignite creative powers.

• Authentic reform is an institutional systemic endeavour. Hence a paradigm shift requires collaborative efforts by mathematics educators, mathematicians, teachers and other relevant contributors. It works within sensibly planned policies, not through stickling politics.

• Experimentation has to precede dissemination. Feed forward and feedback are guarantees for sustainable reform.

Guiding Objectives

Such objectives ought to stem out of the goals and be compatible with the
national standards accepted by the educational system which in turn stems out of the supreme goals of the country. Two main categories are to be considered:

**Societal objectives:**
- Appreciation of the practical use of maths in different areas and activities of the society which serve tools and technologies of production
- Preparation of citizens to the work force in the new technology market
- Development of generic skills such as ability to be independent, work in collaboration with others, open-mindedness, decision making
- Propagation of mathematical culture and methods in the society.

**Developmental objectives:**
- Capacity building, developing number sense and space sense
- Ability to estimate, describe, approximate, compare, make error analysis and deal with probabilistic situations
- Thinking quantitatively and qualitatively; seeing phenomena underlying numbers, tables and graphs and making different representations of given mathematical situations
- Ability to reason rationally, make logical proofs, abstract, induct, deduct, interpolate, extrapolate, ...according to specific situations and appropriate assumptions
- Imagining, inquiring, experimenting and making designs
- Using the language of maths in communication and connections with other areas of knowledge and using mathematical aspects in recreation and educational games
- Differentiating between mathematical proof and mere verification of some formula or generalization
- Demonstrating understanding about ways of working with different types of numbers and other mathematical entities as well as investigating patterns and mathematics related phenomena in social and physical phenomena
- Seeing mathematics as a human product to which all cultures, ancient, medieval, contemporary, have contributed in significant ways
- Analyzing mathematical relationships, so as to allow learners to develop critical thinking and capacity in order to help them to participate in decision-making which affects their life and supports their career.

**Guiding Features**
- In the light of access to technology, shift the emphasis from paper and pencil based operations to basic skills operations
- Organize maths content, at all levels, systemically so as to ensure: unity of thought, inter-relations between ideas across topics and branches, non-linear links among concepts, generalizations and skills. Avoid repetition and linear sequencing to give the learner a chance to predict, discover, construct and acquire generic skills.
- Incorporate, at relevant levels, new mathematical concepts and methods. Examples can come from: data analysis, sampling techniques, probability and dealing with uncertainty, chaos, complexity, patterns as well as with fractals, history and contributions of different cultures in the development of mathematics; activities which reflect aesthetics in mathematical constructions, patterns, methods of reasoning and creative solutions of problems
- Include applications of mathematics in real life situations, which reflect the role of mathematics in different academic disciplines, technological advances, vocational efficiency, social development, personal habits, etc.
- Train the mathematics teachers to work within standards, open-ended objectives and not enclaved in the classic behavioural-based bloom taxonomy.

**Conclusion**
Having decided to describe globalization as a set of extended inter-relations over the world in the fields of economy, culture, politics and civil societies, we must now tackle questions raised regarding mathematics education in the near future. Primarily, this entails asking ourselves how mathematics can be taught in such a manner as to contribute to the developments of globalization while remaining true to its essence as a discipline, meeting shifts/challenges in society/technology. Lastly, we must agree on formulating and adhering to the guidelines needed to navigate this paradigm shift, i.e. Mathematics for All, diverse delivery systems, modern teaching/learning methodologies as well as collaborative efforts on the parts of all relevant contributors to effect systemic institutional change.*

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