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Meeting Challenges to Sustainable Development through Science and Technology Education

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Abstract
This paper is intended to stimulate discussion and recommendations related to science and technology education and its role in sustainable development. It puts forward points of view and addresses concerns in science education. The paper recognizes that all in not well within science and technology education and that there are concerns related to its vision, its philosophy,its research, its approach, its way of meeting needs, its expected outcomes and most definitely in the manner in which it is taught. This paper recognises that science and technology education must do more than simply pay 'lip service' to sustainable development and must focus learning on issues of relevance facing society. It is simply not enough to apply scientific ideas to technological application.The education context must provide the frame for learning. As this is heavily interdisciplinary and related to values, so must be science education. This in turn suggests there is a need to re-exmaine the goals of education and with this the goals of science education. It is suggested that education for sustainable development has little to do with accumulating a body of scientific knowledge and is far more aligned with the development of personal and social aptitudes leading to responsible citizenship.

Key words: *sustainability, sustainable development, science and technology education, paradigm shift, science education issues*

Introduction

The year 2005 marked the beginning of the ***United Nations Decade of Education for Sustainable Development***. It is thus timely to deliberate on *Sustainable Development from a*

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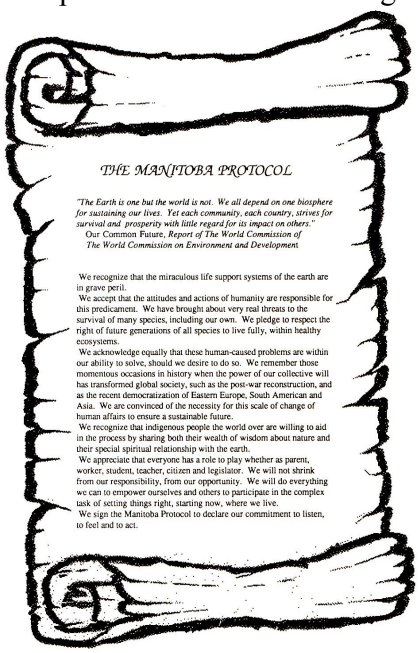
Science and Technology Education perspective. Generally speaking, a school curriculum should achieve three broad educational aims:

- Acquisition of knowledge, skills, abilities or capacities.
- Development of competencies, i.e. the ability to apply the knowledge and skills imparted by education to real-life situations.
- Development of key competencies, i.e. those that are essential in order to participate effectively within society. (Eurydice, 2002)

Bearing this in mind, three key questions arise:

1. Can science and technology education be developed with a view to playing an active role in leading to true sustainable development?
2. What effects are educational institutions and NGOs expected to have during the United Nations Decade of Education for Sustainable Development so as to play a positive role in promoting more appropriate science and technology education (especially for sustainable development)?
3. Can educational institutions (at primary, secondary and tertiary levels) and NGOs have the vision, strength of direction and expertise to enhance greater self-empowerment and guide the abandoning of inappropriate 20th century (and often 19th century) science education practices for more suitable practices that enhance meaningful sustainable development and by so doing, use their power to enhance greater equity and fairness in developing scientific literacy for all?

ICASE has a history of considering the meaning of science and technology education (STE) and its relationship with sustainable development. Even from 1990, ICASE has been involved in the promotion of education for sustainable development, The Manitoba protocol developed as part of an international conference on education for sustainable development, held in Winnepeg, Canada in 1990, in partnership with the Canadian Association for Science Education, enabled ICASE to play a role in drawing attention to education for sustainable development. The scroll containing the protocol is shown below with amplification of the full text given beneath.



THE MANITOBA PROTOCOL

"The Earth is one but the world is not. We all depend on one biosphere for sustaining our lives. Yet each community, each country, strives for survival and prosperity with little regard for its impact on others."
Our Common Future, *Report of The World Commission of The World Commission on Environment and Development.*

We recognize that the miraculous life support systems of the earth are in grave peril.
We accept that the attitudes and actions of humanity are responsible for this predicament. We have brought about very real threats to the survival of many species, including our own. We pledge to respect the right of future generations of all species to live fully, within healthy ecosystems.
We acknowledge equally that these human-caused problems are within our ability to solve, should we desire to do so. We remember those momentous occasions in history when the power of our collective will has transformed global society, such as the post-war reconstruction, and as the recent democratization of Eastern Europe, South American and Asia. We are convinced of the necessity for this scale of change of human affairs to ensure a sustainable future.
We recognize that indigenous people the world over are willing to aid in the process by sharing both their wealth of wisdom about nature and their special spiritual relationship with the earth.
We appreciate that everyone has a role to play whether as parent, worker, student, teacher, citizen and legislator. We will not shrink from our responsibility, from our opportunity. We will do everything we can to empower ourselves and others to participate in the complex task of setting things right, starting now, where we live.
We sign the Manitoba Protocol to declare our commitment to listen, to feel and to act.

The Manitoba Protocol

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ICASE, in conjunction with UNESCO, initiated Project 2000+ in the 1990s to promote the development of scientific and technological literacy (STL) for all students. A worldwide conference, held in 1993, explored the meaning of STL and reflected on STL through 6 major sub-themes : -

Rethinking the philosophy of STL;
Relevant Curriculum Development;
Appropriate Classroom Strategies;
More appropriate Teacher Education;
Rethinking Assessment Strategies;
Informal and Non-formal Education.

The philosophy led to a conference definition for STL as:

"the capability to function with understanding and confidence, and at appropriate levels, in ways that bring about empowerment in the man-made world and in the world of scientific and technological ideas."

It is clear STL is expected to enhance an ability to function, or the potentiality to function, within society for the bettermen of society (Kolsto, 2000, Millar,1996). STL is related to an awareness of the science within society and an awarensss of experts who can provide the understanding that the ordinary citizen may lack (Shamos, 1995, DeBoer, 2000). But further, as the definitions indicate, it promotes empowerment in a democratic society, where science driven technology is playing a greater and greater role.It is about developing an appreciation that side-effects related to health, the sustainability of the environment, or economic concerns can become key factors in choosing the most appropriate science–driven technology (Roth and Lee, 2004; Sadler and Zeidler, 2005).

The 2002 World Summit on Sustainable Development (WSSD) brought together governments, UN agencies and other key stakeholders, including representatives of civil society and the Scientific and Technological Community, to build upon the 1992 United Nations Conference on Environment and Development (UNCED) and to enhance efforts toward the future of sustainable development. Following up the conference, an ICSU committee on Capacity Building held an important workshop producing a report linking the need for capacity building, including education and sustainable development. This paper draws on ideas the workshop (ICSU, 2002).

What is Sustainability and Sustainable Development?

An often quoted source of inspiration related to the meaning of sustainable development is the Report of the Brundtland Commission, '**Our Common Future',** published by Oxford University Press in 1987. The Report was welcomed by the UN General Assembly in its resolution 42/187. The definition put forward for sustainable development is well known and often cited (Brundtland, 1987):

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Unfortunately this is not the only approach to sustainable development. It can be understood in different ways (Barboza, 2000). An alternative meaning can be:

> *"the will to follow a rational approach to economic administration and the creation of economic policies; to manage public matters efficiently and predicably; to show respect and progressively to evolve towards democracy – the full participation of all concerned actors, while taking into account specific local circumstances."*

Both these definitions, and also others, are not without their critcs. And as such they can, depending on the meaning attached to education and science and technology education, be considered as out-of-tune with educational, and therefore science and technology educational, aspirations. It is thus worthy to consider ithe meaning of sustainability and sustainable development further.

Meaning of Sustainability

Sumner (2005) suggests that sustainability involves a set of structures and processes that build the ***civil commons***. From this basic understanding of sustainability, values within the society play an important role. Civil commons is based on values that *promote* ***life first and foremost.*** This suggests it is:

- co-operative, rather than competitive;
- a human construct, not a naturally occurring phenomenon, and
- by definition, built by human agency.

The concept of civil commons was developed by the philosopher John McMurtry (2001) and used to describe "any co-operative human construct that enables the access of all members of a community to life goods," where life goods, or means of life, refer to:

- whatever allows life to be preserved or extended on three planes – thought, feeling and action;

- availability of food (nutritious food), clean water, shelter, healthcare, open space, safe workplace and education.

Civil commons is an expression intended to enable access of all community members, not just an elite group of people, so that everyone has the chance to "grow and express themselves as human" and this community can range from the local through the national to the global community. Examples of the civil commons surround us every day - public education, universal healthcare, environmental legislation, health and safety regulations, and public broadcasting. It is civil commons that is at the heart of a values view of sustainable development.

The civil-commons model of education for sustainable development

Taking this view, ***education for sustainable development*** promotes the accumulation of public, not private, wealth. In contrast to corporate globalisation, sustainable globalisation globalises the civil commons. Women's rights, children's rights, workers' rights, co-operatives, public education, universal health-care, and environmental protection are examples around the world taking shape in different dimensions and in different ways, depending on location.

What are the major Sustainable Development issues for Education?

From an education perspective, developing sustainable development can be viewed as (Ospina, 2000):

- placing a system of values and ethics at the centre of society's concerns;
- encouraging a meeting of disciplines, a linking of knowledge and of expertise, and to render our understanding more integrated and contextualised and so, in turn, to open up new hoizons for justice and equality (equity);
- encouraging lifelong learning, starting at the beginning of life and grounded in life – one based on a passion for a radical transformation of society and a change in the moral character of society;
- advancing new conceptions rooted both in traditional scientific rationality and in popular beliefs and consciousness, drawing on these as a source of human understanding and a pointer to collective wisdom;
- encouraging the refinements of locally based processes of change and of integral community advancement, one not marked by a passive receptivity to or a mindless repetition of homogeneous development models;
- ensuring priority is given to fundamental critical questions, to the method as a means of approaching tangible realities, by promotiong dialogue among the sectors of society and a real interdisciplinary approach;.
- elevating the importance of social subjectivity and of the qualitative dimension of social life;
- encouraging new alliances between the State and civil society in promoting citiznes' emancipation mediated by the practice of democratic principles while fully acknowledging the compexities inherent to every human reality.

For the above to be put into place, it is suggested that ***education needs to be viewed as a means to*** (Opsina, 2000):

- promote a culture of citizenship and give value to social actors (such as non-governmental organizations and other sub-groups);

- mobilise society in a concerted effort so as to eliminate poverty and all forms of violence and injustice that jeopardize the future and the maintenance of a good quality of life;
- valorise aesthetics, the creative use of the imagination, an openness to risk and flexibility and a willingness to explore new options;
- assert the importance of local communitieis and their ties to the entire Earth and indeed with the universal;
- identify and pursue new human projects in the context of a planetary consciousness and a personal and communal awareness of global responsibility;
- engender new hopes and ways of channelling the valuable energies and resources of entire nations;
- seek understanding, to anticipate, to imagine and to contextualise;
- reach a stage in which the possibility of change and the real desire for change are accompanied by a concerted, active participation in change, at the appropriate time, in favour of a sustainable future for all;
- instil in the minds of all people a conviction of the values of peace in such a way as to promote the creation of new lifestyles and living patterns;
- develop to the maximum, the potential of all, throughout their lives, so that they can achieve self-fulfillment and full self-expression with the collective achievement of a viable future; effect change in value systems, behaviour patterns and lifestyles necessary to achieve sustainable development, and ultimately democracy, security and peace;
- disseminate the knowledge and skills necessary to foster sustainable production and consumption patterns and to improve the management of natural resources, agriculture, energy and industrial production;
- ensure an informed populace, prepared to support changes in other sectors conducive to sustainability.

This paints a very different picture to that being advocated by many school curricula today, especially where the teaching is based on factual memrisation, reinforced by high stakes external, pencil and paper examinations!!

How can Science and Technology Education relate to Sustainable Development?
Science, over the last 100 years, has slowly been given a place in the curriculum. Yet its original purpose (to prepare students for science studies at University (Fensham, 2008) has tended to remain the predominant determinant of the content and hence the focus of teaching and learning. The content for learning still carries the strong conceptual tone that characterised the scientific preparation of an elite group, as if they were the sole concern and purpose of school science.

Getting the balance right between the purposes of enthusing enough students to go on to scientific and technological careers and giving ***all students*** an interest in, and enough knowledge of science and technology so as to appreciate the importance of science and technology in society, is perhaps the major science education issue facing all countries today. This suggests that the aims for school science curricula need to be examined, especially with respect to social relevance and hence sustainable development. Equipping young persons to participate in the big socio-scientific issues of today (for example, food scarcity, poverty alleviation, HIV/AIDS/ peace building, global warming, cloning, embryonic stem cell use, toxic waste disposal, sustainable development, etc.) makes good sense in the compulsory years of education.

The Role of School Science and Technology Education

A common expression in many curricula today indicates that the purpose of science education in schools is to enhance ***scientific literacy***. The precise meaning of scientific literacy is unclear and there is much controversy over whether it refers to learning science content, as the intended focus of science education. The ICASE definition of scientific and technological literacy clearly relates to the issues of sustanable development above and beyond specific content. This definition put forward in 1997 (Holbrook and Rannikmae) states:

> *"developing the ability to creatively utilise sound science knowledge in everyday life, or in a career, to solve problems, make decisions and hence improve the quality of life."*

This view of scientific literacy is still very valid today.

'Education through science' as a key component of School Science for Scientific Literacy

Teachers are educators. Education is the area of focus for science teachers and science is merely one learning vehicle for this. The term *'education through science'* is proposed to express the intended emphasis for the teaching-learning approach. This proposed emphasis is thus NOT about stressing the ways of the scientist, any more than history is taught for students to become historians, or language is taught to become linguists. It is proposed that science in school is part of the total education provision and any science content is gained solely so as to enhance scientific literacy. The table below illustrates a comparison of 'education through science' with 'science through education' – the rejected alternative if in the short term, a content approach to science teaching, is considered as the sole basis for the science education proposed.

A comparison of similarities and differences in philosophical emphases between 'Science through Education' and the alternative 'Education through Science' (Holbrook & Rannikmae, 2007)

Science through Education	**Education through Science**
Learn fundamental science knowledge, concepts, theories and laws.	Learn the science knowledge and concepts important for understanding and handling socio-scientific issues within society.
Undertake the processes of science through inquiry learning as part of the development of learning to be a scientist.	Undertake investigatory scientific problem solving to better understand the science background related to socio-scientific issues within society.
Gain an appreciation of the nature of science from a scientist's point of view.	Gain an appreciation of the nature of science from a societal point of view.
Undertake practical work and appreciate the work of scientists.	Develop personal skills related to creativity, initiative, safe working, etc.
Develop positive attitudes towards science and scientists.	Develop positive attitudes towards science as a major factor in the development of society and scientific endeavours.
Acquire communicative skills related to oral, written and symbolic/tabular/ graphical formats as part of systematic science learning.	Acquire communicative skills related to oral, written and symbolic/tabular/ graphical formats to better express scientific ideas in a social context.
Undertake decision making in tackling scientific	Undertake socio-scientific decision making related

issues.	to issues arising from the society.
Apply the uses of science to society and appreciate ethical issues faced by scientists.	Develop social values related to becoming a responsible citizen and undertaking science-related careers.

Consequences of the 'education through science' (EtS) model for science education.

1. The acquisition of "big" ideas in science is relegated to building a concept of the nature of science and/or the promoting of personal intellectual thinking needed to promote sustainable development.
   [This does not mean knowledge is excluded from the teaching of science, but it is a recognition that useful basic knowledge is tentative, liable to regional variations and best included on a need-to-know basis]
2. The key driving force for EtS is the need for students to acquire social skills, supported by personal skills, thus enabling students (and later as adults – Roth and Lee, 2004) to draw on their scientific literacy to play a responsible role within society.
3. Ensuring students are able to function within the world of work at a skill or responsibility level, commiserate with the students' aptitude and ability;
4. Possessing a conceptual background, or skills of learning so as to learn to cope with a need-to-have, relevant public understanding of science and technology in a changing society.

This science literacy trend is thus towards:

(a) inclusion of issue-based or context–based teaching as a major thrust to 'set up' the scientific problem to be investigated (Zeidler et al, 2005);
(b) the need to go beyond scientific problem solving to also encompass socio-scientific decision making (related to responsible citizenry) (Holbrook & Rannikmae, 2007);
(c) recognition that scientific literacy relates primarily to enabling citizens to effectively participate in the real world and is thus a social rather than solely an individual consideration (Roth and Lee, 2004).

Embracing Sustainable Development - The Need for Change

The need for change, from an educational point of view, is based on the overall desire to develop an educational literate society in which sustainable development is understood and appreciated within the context of the environment, basic needs and for promoting a better quality of life, now and for future generations. As such, science education is seen as focussing on persons and societes and backing this up with the study of phenomena and theories taken from scientists. In short, science education needs to be viewed as a part of the social science arena, not merely as a construct of scientists.

Education is the central theme in our lives. It prepares the young generation for life that lies ahead, and it informs adults of the world about them. A transformation in what we teach, how we teach it and the manner in which it is assessed **is crucial** to the major knowledge and attitude changes which are essential if sustainable development is to be a focus, especially in science and technology curricula. It is crucial for students to be educated to give greater consideration to such social attributes as values and ethics. This transformation and progression will involve consultations and agreements and needs the active involvement of those concerned at every level, right up to the senior levels in Government. It will require ***partnerships and the political will.***

To this end, three important criteria for change to embrace sustainably development within science education are put forward as - (a) relevance, (b) practicality and (c) values.

Relevance implies a personal approach appealing to emotions. It involves community interaction and the incorporation of local issues and practices into the curriculum and the learning can be related to the community, often at a local level. The learning is seen in the eyes of the student as meaningful, timely, important and useful. It builds on the intrinsic motivation of the student for self concern, self-involvement, self-appreciation and self-development.

Practicality means activity-based learning (doing and action), with inclusion of learning so as to gain a balanced points of view and training in the recognition of bias. The quality of the science and technology education is thus measured in terms of student abilities to 'do', interact with others and formulate justified points of view rather that simply follow teacher instructions. The actions relate to the competencies to be developed. The learning serves a meaningful purpose.

Values involve cultural issues, personal interdependence and informed judgements both from a holistic view of the world and from a local society perspective. It is heavily related to well reasoned, socio-scientific decision making and can relate to safety, risk assessment, life cycle analysis, quality of life for the community and hence civil commons.

Focussing Science Education for Change

For science education to truly enhance scientific litracy, and through this engage with sustainable development, a number of issues need to be faced which relate to major changes from the current situation, especially at the secondary level or for the pre- and in-service education of teachers.

Issue 1

Adopting a proposed model for which the **teaching of science subjects for all is** through the development of lifeskills (Wikipedia) and the gaining of competencies associated with the interrelationship between knowledge, skills and values. This assumes such a focus is worthy of support.

These lifeskills include (The free dictionary)

Knowledge embracing the cognitive and meta-cognitive components of the curriculum and covering, (not from a 'basic' perspective geared to the same for all, but on a need-to-know basis), scientific, cultural, economic, social and environmental data and structures plus interconnections of systems, methods of enhancing scientific and technological processes and the management of risk and life cycle analysis. It encompasses the meaning and limitations of science, that is, an appreciation of the nature of science.

Skills include the variety of scientific methods (process skills) but also reasoning, argumentation, decision-making, problem solving, communication and inter-personal skills. It goes beyond the simple 'doing' and into a minds-on/hands-on interaction.

Values, as the pinnacle component, places emphasis on a respect for life, the quality of personal life, aesthetics in nature, ethical/moral issues and cultural and societal priorities. The development of such values is seen as a priority goal for science and technology education as it places scientific phenomena within the society rather than seeing science as an endeavour external to the society.

Issue 2
What to assess? Is 'assessment of learning' (students' summative achievement, seemingly as a fixed status devoid of community values) the key target, or is it 'assessment for learning' (assessment so as to aid the progress of all students in their learning)? And if attributes related to sustainable development/civil commons, within a science course, are **not assessed**, will they be taken seriously and be taught during formal classroom teacher/student interactions?

Present assessment systems are highly demanding in terms of summative pencil and paper measures, but place little value on assessment activities geared to social values and development. This results in teaching paying scant attention to the development of personal and social skills, especially in science subjects.
This issue thus relates to an appreciation of the potentially crucial role of formative assessment for enhancing education for sustainable development as well as scientific literacy.

Issue 3
Change needs to be systemic. It is of little use to make bold changes in pre-service and in teacher continuous professional development education, but leave the assessment system unchanged, or continue with teacher education approaches which ignore personal and social values linked to education for sustainable development.

Systemic changes would imply possible changes in:
1. the educational system, its organization and support system,
2. curriculum orientation including content and assessment strategies.
3. teacher education or teacher continuing professional development (CPD)

Systemic changes also imply the need for greater flexibility, with greater attention to education and less to bureaucratic expedience. Flexibility is needed in areas such as timetabling - to allow for fieldwork and field trips; additional preparation time for teachers for activity-oriented work and the changing society; support materials and support technology to keep pace with the learning expectations of the young, inculcated by society; and acceptance of teachers' ability and need to deal with controversy and bias based on value judgements.

In a context-based teaching approach, *content* is not the focuis, rather content is embedded in the teaching to better appreciate the socio-scientific situation and is inevitably less factual while giving more attention to developing skills, particularly in the areas of communication, problem recognition and solving, and informed, balanced decision-making. Such changes imply changes in assessment strategies so that values education is given more prominence and skills such as problem solving and decision-making are embedded in the learning. Facts are derived from suitable sources as and when needed. This is very much in line with today's knowledge-based society where the knowledge base is made widely available with the textbook being but one of many suitable sources.

Relevant, Practical and Values-laden Science and Technology Education for the promotion of Sustainable Development

The issues put forward suggest the need for a number of major changes in the orientation and development of science and technology education. Five paradigm shifts are put forward, each suggested as playing a key role in enhancing science education for sustainable development.

Paradigm shift 1 Ensuring the purpose of science education is scientific literacy (in terms of relevance, practicality, values)

The following targets were put forward at the ICASE World Conference, held in Malaysia in 2003 (ICASE).

1. The Goals of science and technology education (STE) should be solely derived from, and relate to, the Goals of Education.
   Why should many teachers and the General Public think that science education is anything other than a component of Education ?
2. Achievement should be measured in terms of the degree to which students acquire scientific and technological literacy (STL) to the standards determined by the society.
   Assessment strategies and techniques used in schools should be expected to measure student achievement of all the Goals of Education. Without that, the science education provision is distorted and STL and sustainable development no longer remain targets.
3. STE should be a core provision within the school curriculum at all levels and be expected to provide a basis for acquiring skills for lifelong learning related to sustainability. In today's technological society, few would argue against attainment of the Goals of Education through inclusion of a school science, or science and technology provision.
4. Standards should be set for the STE provision, related to enhancement of STL, and student assessment should be criteria referenced on the basis on these standards.
   The attainment of the Goals of Education need to be set against standards based on appropriate and measurable criteria. The standards need to recognise the need for multi-dimensional STL associated with learning associated for sustainable development.
5. STE needs to give due attention to the STL approach in terms of relevance to the student, to industry and to the expectations of society and be based on constructivist principles. The teaching strategies need to be conducive to the promotion of student- relevance of learning, appropriate for all and meet society expectations.
   The approach needs to recognise the need for 'Education through Science.'
6. Greater efforts should be made to encourage research into STE, disseminating its results and supporting the implementation of recommendations.
   The gap between research and practice needs to be made smaller. Such research can be international, national, regional as well as classroom based (action research).
7. The validity and reliability of student assessment in STE should be increased and made more relevant to the achievement standards set for STL enhancement.
   Paying greater attention to formative, not just summative, assessment is seen as important.
8. Greater provision should be made for the continuous professional development (CPD) of STE teachers to promote relevance in the teaching provision for the enhancement of STL.
   At present teachers are caught between the views of scientists (Science through Education)

and the views of Educationalists (Education through Science).

9. Provision should also be made for the ongoing professional development of STE teacher educators (those leading the pre-, or in-service STE provisions).
   CPD for the 'training of trainers' needs to recognise as a key provision.
10. Official support (especially in terms of recognition) should be forthcoming for professional STE teacher associations.
    'Teacher helping teacher' is a powerful approach to CPD. Professional Science Teacher *Associations must be recognised by all stakeholders as playing an essential role in guiding teachers to enhance STL among students.*

Paradigm shift 2. Taking greater measures to enhance and sustain student motivation in and about science, thus enabling science and technology education to play a role in education for sustainable development.

Science education is notand cannto be the same as science. It is important to be reminded that students go to school to be educated. And school science is part of that education. Thus, whereas science can be associated with a body of knowledge or, if you prefer, a way of thinking, science education must differ and be associated with the **acquisition of educational goals** through the medium of science. And as such it incorporates the person and social development of students as part of enhancing scientific literacy for all and an appreciatin of sustainable development.

Policy makers should consider mandating that science and technology education should move progressively (as has been done in several countries) towards a real world, "context-based" approach to the teaching and learning at all levels of the school curriculum. This has been shown to promote student interest and raise the level of relevance of the learning. (Fensham, 2008)

It should be noted that context-based teaching needs to build on a strong conceptual scientific base. With the added benefits of deeper learning, transference of the earlier learning to novel social situations can be promoted. Issues of sustainable development such as food scarcity, poverty alleviation, HIV/AIDs, education for peace, all provide very appropriate contexts for science education.

Paradigm shift 3. Enacting more effective teacher preparation/ professional development for science and technology education and determining the role of the teachers geared to professional development for sustainable development.

Teacher education needs to include techniques whereby teachers are able to function beyond textbooks and be able to design teaching materials that can emphasise the affective domain, plus decision-making and problem solving skills. Teachers also need guidance is dealing, more adequately, with sensitive issues within sustainable development, including bias and conflict.

Quality science learning time, even if less, is preferable to the damage done by under-equipped science teachers (Fensham, 2008). To achieve a goal of equity in science and technology education promoting education for sustainable development, professional development priorities should be given to raising the inter-disciplinary content knowledge and confidence of weaker science and technology teachers.

Science Teacher Associations, as representative bodies for science and technology teachers, have insight and experience of the present problems associated with access to science and technology education. As such they should take practical responsibility for ensuring that their members are equipped to remove any implicit barriers in their teaching that limit access and exclude some groups of students.

Policy makers should review the participation of boys and girls in science and technology education for sustainable development and seek to implement actions that reduce the explicit and implicit non-relevant and anti-social factors that still disadvantage girls in their access to the fields of science and technology.

The role of the teacher will inevitably have to change. Teachers will need to become more involved in facilitating changes of attitudes and guiding students to gain values and access knowledge sources rather than merely teaching factual knowledge. With a general information and exchange system in place, teachers will need to be able to coordinate with other teachers across nations and across continents. To aid this, science teacher associations have formed links through an international umbrella - the International Council of Associations for Science Education (ICASE).

Paradigm shift 4. Placing greater emphasis within student learning on an understanding of the Nature of Science and Scientific Inquiry (Abd-El-Khalick, 2004: McComas, Almazroa & Clough, 1998; Lin and Chiu, 2004), noting their importance for the promotion of sustainable development.

Policy makers should consider what will encourage a better balance between teaching science as established yet often irrelevant information for today's world and those features of science that are referred to as the Nature of Science and relate to civil commons aspects of sustainable development.

Recommendations on the practice of science and technology teaching were put forward by ICSU (ICSU, 2002)

- Quality hands-on science education should be provided which relates to girls and young women (as well as boys and young men) at primary and secondary levels and attempts to counter balance the current female under-participation in terms of general education, science and mathematics courses, jobs and careers. It is also critical to recognize the need to provide quality access to science education, because of women's roles within the family, the community, society and the economy.
- teach science through inquiry - based, hands - on approaches. These should help in the development of science programmes that incorporate topics important in sustainable development, such as health, energy, food production, and the environment, while providing basic conceptual frameworks for the science and technology essential for lifelong learning.
- Problem- based approaches that are more interdisciplinary as well as fundamental ideas of the disciplines should be included in teaching science, especially where these approaches address local issues related to sustainability.
- Information should be made widely available on resources for science, mathematics, and technology education, including such elements as models effective in attracting girls as well

as boys and low cost models for lab and field-based science instruction at the secondary level.

- Internet -based resources, paired with extension workers and scientist volunteers, have the potential for wide distribution and widespread impact. Scientists and engineers must have increased interaction with teachers to provide ongoing support for quality, hands-on science instruction in schools.
- Group work among students and multidisciplinary training should be promoted. Students pursuing studies in any single discipline should be required to take at least a course in another discipline or a multidisciplinary subject of relevance to sustainable development.

Paradigm Shift 5. Recognise the crucisal need for the setting up of effective partnerships.
All stakeholders, including local governments, non-governmental organisations, the industrial sector, learned (science) societies, schools and community groups, need to participate in the sustainable development efforts. Human resource development should focus the development process to increase their knowledge, skills and understandings, and to develop the attitudes needed to bring about the desired developmental change.

There is the need to bringing together a wealth of knowledge, values, approaches and experiences that can and must mutually enrich each other. In particular the multiplicity of forms and systems of knowledge about nature and the human being that have developed over centuries in different parts of the world, prove today to be an invaluable asset in meeting the challenges of sustainable development. In fact, a considerable number of documented experiences indicate that traditional and scientific knowledge play a complementary role and there is a need to cooperate more closely than they have so far, to advance the much needed understanding of nature and its interaction with human beings.

More efforts must therefore be undertaken to build a fair relationship between scientific and traditional knowledge, to strengthen the capacity of communities to revitalise and manage their own knowledge base, and to promote the integration of local knowledge, values, traditions and practices, in sustainable development projects. National partnerships are seen as crucial in meeting the need to ensure general support for moving science education forward in promoting sustainable development which is seen as essential for more responsible citizens, improved human rights, and developing a universal culture of peace.

The 2003 World Conference endorsed the notion that partnerships need to play a key role in gaining the confidence of the general public in science education so as to.

- Reflect on the perceived directions for science education being advocated.
- Ensuring there is really no difference between the teaching of conceptual science (with its content base), and the Goals of Education?
- Make scientists aware that science education is actually a separate discipline from science.
- Enable the recognition that Science Education needs to promote all Goals of Education.
- Expecting Science Teachers to call themselves educationalists first rather than first of all stating they are scientists.

Proposed partnerships for meaningful Science Education for sustainable development were recognised as covering (ICASE, 2003):

A. Government policy makers
B. Curriculum developers
C. Teachers of science and technology education
D. Teacher educators
E. External examination authorities
F. UNESCO and International non-Governmental organisations (NGOs, such as ICASE)
G. National science (and technology) education, professional teacher associations
H. Industrialists
I. Scientists, or science academies
J. Science centres & science museums

The Obstacles to Change

Alas, there are many obstacles to change even if financial conderations are omitted. For example, change:

- is disruptive of habits and values held by parents and students;
- affects the morale of teachers if handled badly.

It is a sad fact that change is often resisted. The attitude of many individuals to the need for change, which is unfortunately reflected by decision-makers, administrators and policy-makers in education, including politicians at the highest levels of Government, may be summarised by one or more of the following:

- Since we do not know all there is to know, we wait to act in case we may not have to act at all;
- Because there is no historical precedent for what is happening we refuse to believe it is happening (this is the 'there is nothing new under the sun' syndrome);
- It will be easier to adapt than try to change (this is the 'we will evolve out of the problem' syndrome);
- Lack of widespread awareness among the general public and among political leaders;
- Because the problems are so severe, their solutions will be difficult - very difficult (the 'we may fail, so why try?' syndrome).

And to reinforce the point, this paper suggests decision makers are not the only point of resistance - this trait is often identified with teachers in school. This in turn suggest that more research is needed into the degree of resistance to change to be found in **tertiary establishments** and in the approaches to the **education of future science and technology teachers.**

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