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FOREWORD

Rethink Science Education

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Introduction

Whereas change in school science is slow, the pace of scientific and technological development within society is great, so much so that there is a danger that the changing world leaves science education behind. This is not only in terms of content and its related conceptual understanding, but also in its approach, its field of operation and the skills demanded of the teacher. In addressing these concerns, research in a science education context has tended to focus on the following problem areas:

(a) the unpopularity of science subjects among students, where less and less students are thinking about careers in science and further study in science related areas (Krajcik et al., 2001; UNESCO,1999);

(b) the irrelevance of science for students as taught in schools. Students do not see science useful for their lives and future developments (Osborne & Collins, 2001; Holbrook, 1998; Pak, 1997; Yager, 1996);

(c) the static nature of the science content, overloaded with facts and theories taken from the past (Krajcik et al., 2001; Rannikmae, 2001). This bears little relationship with everyday needs;

(d) student perception of school science as dominated by content with too much repetition and too little challenge (Osborne & Collins, 2001; Sjoberg, 2001);

(e) isolation of science education from the values components of education and communication. Science education tends to be portrayed as value free, yet at the same time, the community needs increasingly to address moral and ethical issues and related problems (Anderson, et al., 1992; Holbrook, 1992; Layton, 1986);

(f) teaching that is lacking attention to higher order learning among students has limited the development of problem-solving and decision-making skills among school graduates (Anderson et al., 1992; Zoller, 1993; Tal et al., 2001).

These areas of focus are interrelated, even though they are addressing and highlighting issues in different contexts of science education. In general, all can be discussed within two domains: teacher's lack of training to teach higher order cognitive skills (problem-solving, decision-making) to students, and concerns for the context in which the science content is taught by teachers.

It seems there is a need to rethink the rationale for teaching science in schools. Essential to this is determining the meaning of "science education", or "school science" and its relationship, if any, to other subjects in the school curriculum. A major consideration is to consider the place of science education within the context of education as a whole. Students go to school to be educated, or if you prefer, all that happens in schools is related to education. This on the face of it is similar to the perceived need for a paradigm shift in education to meet the need to become contextualised multiple intelligence citizens (Cheng, 2001), but while Cheng concentrates on science learning strategies and the role of the science teachers, the need seems to go much deeper. There is a need to question the role of science education within education.

The role of science education

Is the role of science education to provide one part of education, such that the sum of the parts (the various subject offerings and other aspects) adds up to the total? In this concept, each part is playing its own, specific role. All too often the teacher perception seems to reinforce this view. Or is school science to be considered as addressing the goals of education and is thus to be viewed as a subdivision of education? In this concept, each sub-division is trying to meet all, rather than some, of the stated goals of education. With sub-divisions geared to reinforce all goals of education, these sub-divisions can vary from one system to another. The actual sub-division studied is not so crucial and there is scope for integration, thus limiting in-depth conceptual study in favour of a wider view of the education provision The rethink needed to make science education more popular and appropriate is that the totality of the goals of education apply to **all** sub-divisions i.e. each of the subject areas within the curriculum. It is thus proposed that all subject areas need address the ***same goals of education*** and in this way each cover the full width of the education provision stipulated in policies within a system.

Thus, for example,

- if the development of communication skills in oral, written, and symbolic forms is an education goal, then this becomes a specific goal for science education.
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And it follows:

- the goals of science education are determined by the goals of education.
- the major task of the curriculum developer is to determine how best these education goals can be achieved *through* the science provision within the curriculum and the experiences students need to acquire this.
- these experiences lead the student to be *educated through science.*

Relevance

A major factor in making science in school more popular, and expected to lead to greater public awareness of science by students in the future, is the relevance of the learning in the eyes of students.

- Students need to see the relevance of the learning, as it applies to them personally (their own lives, their career expectations, the wishes of their parents), or the relevance as it applies to society (wishes of the community, employers, the school, the curriculum).
- Thus, while the science provision in school, i.e. the science (or science and technology) education, is expected to guide students to achieve the goals of education through science, there is also the motivational factor to consider.

- Students learn when they are motivated. Making the science education provision interesting to students, illustrating that the provision is important in helping determine a career, and showing how it is of importance for them as a responsible member of society, is important.
- It is important for students to better appreciate the relevance of the science component in their education.

Science education courses need a relevant structure
Scientific conceptual development is important. Intellectual development through science is likely to be one of the major education goals in all societies. The development of reasoning skills and the promoting of logical thought, associated with investigatory skills, are still important.

But the strive for relevance of science education does suggest that

- the manner in which the teaching is approached needs re-consideration.
- the relevance for the subject is more apparent coming from society and especially from those aspects of society that directly impinge on the student.
- the structure of the teaching, initiated from society concerns, allows the learning of science to better impact on its relationship with society.
- the structure of science lessons is less about putting forward a series of scientific and technological conceptual topics that are, certainly at the lower levels of schooling, unrelated to the science and technology around us.

A New Philosophy

The rethink of science (or science and technology*) education requires consideration of a philosophy for the "education through science" provision. The philosophy needs to address the **lack of popularity** of science in schools and to lead to a provision that better prepares students for life within society. In so doing, it needs to provide students with a **better awareness** of science and technology within society.

Note that it is important to distinguish between

(i) science (a body of knowledge, or perhaps more appropriately, a way of knowing) and
(ii) science education (education provided through science).

*While science and technology differ, there is little evidence that science education differs from technology education. The combined expression is thus the same as or no better than the single entity, but may reflect a more society oriented teaching.

While science teaching can be taken to be equivalent to science education, care is needed when using the term 'science', or 'teaching of science' so as to avoid confusion between a 'way of knowing' and 'acquiring educational goals'. The latter, of course, includes the gaining of knowledge as well as a way of knowing, but it also relates to values, development of personal attributes and the gaining of communication skills (assuming these are goals of education).

The "education through science" to which students strive can be referred to as education for scientific and technological literacy (STL). This literacy is far from a simple consideration of reading and writing and covers all the goals of education from knowledge, to skills, to values within a science and technology context. It certainly includes critical and political scientific literacy (Hodson, 2002). However the meaning of literacy, in STL differs, depending on the education received and the educational objectives stipulated, at a given educational level, within a specific country.

In the context of the new philosophy put forward, STL means 'developing the ability to creatively utilise sound science knowledge (and ways of working), in everyday life, to solve problems, make decisions and hence improve the quality of life' (Holbrook and Rannikmae, 1997). This is based on acquiring educational skills involving intellectual, attitudinal, communicative, societal and interdisciplinary learning. It identifies with the meaning of scientific literacy put forward by PISA 2000 (OECD, 2000) "scientific literacy is the capacity to use scientific knowledge to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity".

Within formal schooling, STL may be more appropriately defined as 'that science and technology education which is intended within the school curriculum to maximise the role of science and technology education in aiding students to acquire the goals of general education, as stipulated by society within a country'.

The operationalisation of the STL philosophy is based on effecting **paradigm changes** in science education.

PARADIGM CHANGE 1

Science Education is part of Education

This seems so obvious, but it seems to be poorly understood. Students go to school to be educated. The education is determined by the overseeing body, often the Government, and is expressed through its education policies. These policies, and the goals that are derived from them, represent the needs and aspirations, as felt by society (at least in a democracy) and are designed to meet society's perception of schooling. The goals may be expressed in modified formats for different age levels. Unfortunately many science curriculum developers tend to forget that education is the rationale for schooling and science education is an integral, not a separate, part of this.

The goals of education, as put forward by those responsible for education provide the main target for all subject areas, including science subjects.

These goals seem to be somewhat similar across countries and tend to encompass the following 5 learning areas: *Intellectual, Communicative, Social and Moral, Personal and Physical, Aesthetic*.

Where education is delivered through subject-based lessons, it is necessary to ensure that the various subject lessons address these goals of education. This is not contentious and is really simply stating the obvious. Science lessons need to be seen as playing their part in ensuring students achieve the goals of education. This is a major consideration

What is problematic is

- the weighting to be given within science lessons to the various educational goals so that a fair balance is provided to the majority of students.
- the degree to which science lessons should cover the range of educational goals, and following on from that, the emphasis to be given to any one educational goal within science teaching.

These are the real questions facing science curriculum developers.

PARADIGM CHANGE 2

Science Teaching is approached from a Societal Perspective

The teaching of science needs to be relevant (Holbrook, 1998). It is much easier to learn when something makes sense and is related to one's life, interests or aspirations. Putting forward science as isolated facts, or unrelated theories can be expected to lead to memorisation and the development of poorly conceptualised learning, or even misconceptions.

In the past, students have been shown to be very good at memorising and it is probably true that the more able students tend to have a greater capacity to memorise and regurgitate such information in an examination. But this is not learning that is likely to lead to public understanding of science and technology within society.

For a scientist, relevance of science may well come from the orderly arrangement of facts, postulates and laws. The arrangement of science, starting from the fundamental building blocks and its development into more and more complex ideas, is logical and usually well understood by scientists. It allows patterns to be created and generalisations to be formed, thus lowering the need for memorisation of isolated facts.

However, **the student is not a scientist** (and noting the low percentage of scientists worldwide, is unlikely to become one). The student cannot be expected to have the extensive background that will enable him or her to appreciate patterns and how the fundamental building blocks form the basis for making sense of the scientific world. Nevertheless, students do have some knowledge about society. They live in the society and are aware of relevant issues in that society. They have constructed many conceptual ideas and are aware of many concerns within the society. ***The society is really the students' frame of reference***.

It would seem appropriate, therefore, for science taught in schools to attach more importance to its links to society and be made appropriate for that society, either at present, or in the future. Only in this way is it likely to be seen to be relevant by students. It thus follows that a fundamentals based science curriculum, approached from a scientist's point of view, needs to be challenged. A frame of reference needs to be taken, which relates to the issues and concerns of society (both present and futuristic) as appreciated by students*.

The science ideas to be included needs to be:

- a stepping stone to solving, or making decisions about the concerns or issues;
- introduced on a 'need to know' basis, relevant to the issue or concern;
- bound by the society. The extent and depth of treatment is governed by the society;
- relevant to the students at their current stage of development.

However, it is important to realise that the STL philosophy is more than simply relating science to society. It is not science conceptual ideas, followed by society ideas. The philosophy behind STL teaching is that the science conceptual learning, an essential component of science education, **is embedded within** the resolving of a societal issue or concern relevant to the student.

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* The emphasis on issues and concerns seems to be important. Just because something is related to everyday life does not automatically mean it is seen as relevant to students. The relevancy is likely to be linked to the immediate concern or issue of the society, expressed in the media and impinging on the students' daily life.

The science conceptual learning and associated higher order cognitive skills (the education in science aspect) are acquired **to aid** the problem solving and hence help students be in a position to undertake socio-scientific decision making. This is then taken into account, alongside other attributes e.g. economics, or environmental factors, which may need to be considered in the decision-making process by which the issues or concerns are addressed. However, the science conceptual component will be a major factor in the decision-making, because the teaching is taking place in a context of science within society. This leads to a very different approach to science education and tends to suggest tat there is no "basic" science in school science and no essential "big ideas" that need to be incorporated within school science.

PARADIGM CHANGE 3

Science Education is based on Constructivist principles
Constructivism, and the need for students to form overt constructs, appropriate for learning, is at the very heart of STL (Lutz, 1996). By embedding the science conceptual learning in a social issue or concern and ensuring the science is seen as relevant in the eyes of the student, it is inevitable the teaching builds on students' prior constructs, or ideas. These prior constructs, or ideas may have come from interactions within society, or earlier learning within the school.

Using a teaching approach that makes a student's prior constructs overt, necessitates the emphasising of student involvement. For the teaching of science subjects to be more relevant for students:

- there is a need for student participation in the choice of social context for science learning;
- an increase in student activities and with this greater opportunities for student self learning;
- there needs more potential diagnostic measures of the effectiveness of the teacher;
- this calls for maximising student involvement and the important move away from teacher centred approaches.

The STL (scientific and technological literacy) approach that is proposed here is very different from the un-contextualized emphasis on scientific principles and concepts used in most textbooks. The science and technology within society is often very complicated and demanding in conceptual understanding. So the STL approach needs to find ways to meet this challenge. The constructivist learning builds from constructs previously held by students. Students are definitely required to think (minds-on), but the depth of treatment reflects the 'need to know' required for the learning being promoted.
The inclusion of scientific principles and scientific concepts within the teaching and teaching materials marks a strong demarcation between social science and science

teaching. Although the approach is societal, the conceptual learning is still an area of emphasis. The demarcation between social science and science is NOT made, as is often the case where teaching rigidly follows the textbook, by the simple addition, or absence, of values education.

Implications for Teaching

The teaching approach is based on the following criteria:

a. ***The stipulated educational goals***	Outcomes are specified in achievable terms for a theme or particular set of lessons, which interrelate to a scenario. At least one outcome is put forward for each educational goal area. Care is required that both social factors and conceptual science learning are included.
b. ***Beginning from a societal perspective***	Based on constructivist ideas and in an attempt to maximise interest, the teaching of topics begins from an issue or concern in society relevant to the student. Preferably the students' identify the issue or concern. At first glance it can be taken as encompassing everything. The crucial guideline is that the teaching covers an area of study from an issue or concern perspective that is seen by students as having relevance, or students can be persuaded to appreciate its relevance.
c. ***Promoting science learning***	Students are **NOT** expected to have acquired the science concepts prior to the teaching. If the concept is complex, the number of teaching lessons will increase to reflect the learning. Students can be expected to carry out a number of appropriate activities from interpretations, to textbook reading, to undertaking practice through feedback exercises.
d. ***Enhances Student participation***	If constructivism is to be put into practice, it is essential for students to be involved. This is achieved by student involvement in the thinking, doing and expressing of the learning. Students are thus expected to be involved: (i) Individually, in written work, making presentations and taking part in brainstorming

	sessions. (ii) in small group work - for problem solving, investigations, experimental explorations and discussions on findings, or exploratory ideas or making decisions that involve multiple factors or in preparing for class presentations (iii) as a whole class - for brainstorming and making commentary on group presentations, or arriving at a class consensus decision making position.
e. ***Relating student activities/tasks to the outcomes***	The activities put forward for students need to be clearly related to the learning, thus promoting the achievement of the specific outcomes set out for the teaching of the topic. As the outcomes cover all educational goal areas, the tasks also relate to these (not necessarily on a one-to-one correspondence, because activities may cover more than one outcome, or activities may only partly relate to any one outcome to be achieved). The link between the outcomes and the activities is crucial.
f. ***Engaging in scientific Problem Solving and socio-scientific Decision Making Activities***	This is very dependent on student involvement. If the learning begins from an issue or concern, there needs to be a scientific component that ensures the study is an integral part of the curriculum (without that it is not science education !!) Scientific questions arise from the issue/concern (a problem), which can be investigated scientifically to arrive at a 'solution to the problem', once the students have acquired the relevant conceptual understanding. If in the real world, the scientific solution cannot be taken in isolation, or if the *Problem Solving* (PS) investigation leads to more than one plausible solution, then a socio-scientific *Decision Making* (DM) activity is needed to determine the 'best' or 'appropriate' choice. For this it is essential to consider all the factors involved, then decide on the relative importance in arriving at a decision, based on careful deliberations. One of the factors involved in the decision-making process will derive from the science conceptual learning, whereas others are

	likely to be economic, social, environmental, political or ethical/moral factors. Decision-Making is based on factors that are not always stable and the decision can shift with time, circumstances and public opinion. This does not detract, however, from the important learning process for students in going through the Decision- Making process and learning to justify their stance.
g. ***Assessment linked to achievement of the objectives***	It is essential that assessment measures student achievement in terms of the outcomes put forward and not merely record students' involvement in activities. Thus, recording that students took part in a discussion (an activity) says nothing, whereas stating that students were able to put forward a decision with appropriate justifications shows students achieving the outcome set in this area. The assessment of students will be both during and after the teaching. An advantage of assessing during the teaching process is that multiple measures can be obtained over time, leading to a more relevant measure of the skill measured. Thus observation by the teacher is likely to be an important assessment tool alongside interactive oral work and student written records.

End Note

If this philosophy is so correct and the attributes on which it is built so true, then why is it that the widespread operationalisation of science education in this direction has thus far not materialised in the classroom ? Responses to this need to draw attention to the expressing of school science curricula in terms of content. While this approach is undertaken, the content seems to drive the context and the "scientist ideas" take precedence over "society ideas". Where content free approaches are advocated (e.g. NZ science curriculum, 1994), the learning objective and suggested teaching ideas become paramount. However teachers have yet to be comfortable with such an approach.

It seems that much responsibility for the current state of science education rests with the "trainers of teachers" i.e. the teacher educators. It seems their philosophy of science education is suspect, possible because teacher educators do not appreciate why science education is part of the curriculum and tend to adopt a view of science education being an isolated and discrete part of education having its own goals.

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