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Education through science as a motivational innovation for science education for all

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Abstract
Historically, science was introduced into the school curriculum to enable students, who were entering university to study science related subjects, to gain some background knowledge before beginning studies at the university level (Fensham, 2008, p 14). Unfortunately this view is still very prevalent among policy-makers and teachers today. And this is so, even though science subjects have become part of 'education for all' and, in most systems, science have become compulsory for primary school students. This paper considers the roles of science education as expressed in curriculum documents and in educational standards. It notes the often expressed target of science education as enhancing scientific literacy and puts forwards views on what is meant by this expression Also noted is the comment in the UNESCO booklet on the Eleven Emerging Issues in Science Education (Fensham, 2008, p.8 and 27) that the term 'scientific literacy' should no longer be used. The papers argues that policy-makers and teachers should rethink their vision of science in the school curriculum and accept the view that the teaching of science subjects is part of the overall educational provision and must not be viewed in a different philosophical light from other subjects. If education is the target, then the philosophy for the teaching of science subjects must be, it is argued, 'education through science'. This view represents a paradigm shift in the purpose of school science education from the historical view. The new vision is put forward as an essential step if school science education is to play a meaningful role for the majority of students, especially girls, in 21st century education.

Key words: *Scientific Literacy, education through science, science through education.*

Introduction
Initially (19th century), science (or science subjects) was included in the school curriculum to provide a background for students to better cope if they chose to study science subjects at university (Fensham, 2008). But today, and especially after the Education for All conference

(UNESCO, 1990), there is a general recognition that science teaching in school (*let me call this science education*) has a much wider purpose.

A common rationale given for studying science subjects in school is the achievement of scientific literacy (AAAS, 1989; Bybee, 1997; OECD, 2003, Brown, Reveles & Kelly, 2005; Shwartz, Ben-Zvi, and Hofstein, 2005), although there are different interpretations of its meaning (Jenkins, 1990; DeBoer, 2000; Laugksch, 2000; Tippens, Nichols & Bryan, 2000; Kolstø, 2001; Hodson, 2002; Fensham, 2004). This paper sets out to establish the nature of science education (NSE) needed to prepare students for the kind of scientific literacy necessary for responsible citizenship. It proposes that abilities in a range of educational goals, including socio-scientific decision making and scientific problem solving, are more important for enhancing true scientific literacy (Shamos, 1995), or multi-dimensional scientific literacy (Bybee, 1997) than a systematic, basic understanding of fundamental content knowledge (AAAS, 1993; NRC, 1996).

Meaning of Scientific Literacy/Scientific and Technological Literacy (STL)

As indicated in the introduction, the teaching of science in school is being accepted as enhancing scientific literacy. Noting that developments within society are largely of a technological nature, it is proposed that it is more appropriate to consider scientific and technological literacy (STL) in appreciation of the role science has played and is playing in technological developments within society (UNESCO, 1993; Holbrook, 1998).

While communication skill is accepted as a crucial component of literacy - referred to as literacy in its fundamental sense, rather than a derived sense, by Norris and Phillips (2003) - it is difficult to see how any approach to STL is bound simply by language, or by a dominance of the written text. Scientific and technological literacy is much more than language proficiency, as the French translation as "culture scientifique et technologique" (UNESCO, 1994) strongly suggests.

The scientific thrust of STL has its focus on conceptualisations of need-to-know scientific knowledge, in contrast to many school curricula which still place high emphasis on an all encompassng knowledge component. The latter make student learning overloaded and problematic when it is considered that the science subject area is expanding in content at a faster and faster pace (Schibeci & Lee, 2003). It is argued in this paper that knowledge for its own sake, and hence communication linked to such knowledge (Norris and Phillips, 2003), needs to give way to knowledge and communication for an ability to function, or the potentiality to function, within society (Kolstø, 2000, Millar, 1996). Although this may be seen as covering an understanding of the science underpinning the technological advances of today, that is a still a gigantic undertaken and beyond the ability of any one person (Shamos, 1995). Shamos, in fact, recognised that global understanding of science in society cannot be seen as a target for school science education. Rather, STL can relate to an interaction of the science within society and an awarensss of opinions by experts who can provide the understanding that the ordinary citizen may lack (Shamos, 1995; DeBoer, 2000). But that still does not cover the enabling of decisions to be made in a democratic society, where science driven technology is playing a greater and greater role. Nor does it develop an appreciation that the advantages of technological developments can be great for some, but a major disadvantage for others. Furthermore, side-affects 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). STL is seen as embracing all of this.

This view of STL suggests responsible citizenry as a major focus, in which scientific knowledge is used wisely for the benefit of society. Roth and Lee (2004) and others (Jenkins, 1999) have called this citizen science. It strongly includes the personal and social domains alongside an appreciation of the functioning or nature of science. And where its teaching is seen in the context of issue-based or context-based learning (Zeidler et al., 2005), the scientific ideas are limited to the issues at hand. However, this does not eliminate the inclusion of a historical perspective, nor exclude teacher knowledge inputs alongside student constructivist learning.

> *"School science education needs to respond to a changed social context and to help prepare young people to contribute as citizens to shaping the world in which they will live"* (Jenkins, 1999*).*

A single, simple definition of STL or scientific literacy is always likely to be extremely problematic. The inclusion of a social and personal domain concept of scientific literacy, promoted in the ICASE-UNESCO forum on scientific and technological literacy for all (UNESCO, 1993), suggested scientific literacy 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".*

A later definition by ICASE, intended to involve the nature of science, the personal and the social domains, but also stressing socio-scientific decision making, is (Holbrook and Rannikmae, 1997):

> *"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".*

Such refocusing of science education leads to a strong expectation for science to be an essential, or core subject in the school curriculum, for the benefit of all students. In line with this, curriculum developers are increasingly indicating that the overall goal of science education is scientific literacy. Unfortunately, the very need in promoting scientific literacy through developing wider reasoning skills and guiding students to draw conclusions (Sadler 2004; Sadler and Zeidler, 2005), to guide students to develop argumentation skills (Driver, Newton & Osborne, 2000; Osborne, Erduran & Simon, 2004) and to make social judgemental decisions utilising scientific ideas (Ratcliffe, 1997; Kortland, 2001) that science education becomes problematic for teachers. Yet, without this, there is the danger that an over-emphasis on content overshadows acquisition of educational goals and thus inhibits the promotion of multi-dimensional levels of scientific literacy (Bybee, 1997) for functioning within society.

The Goals of Education

Each country has explicit statements for the direction of their education provision. These statements may be called – aims, goals, general objectives, targets, standards, key competencies, etc. They are likely to cover, for example, the development of: cognitive abilities, personal attitudes, personal aptitudes (behaviour/skills), communication skills, social values, social skills and aspects of self-efficacy. These goals are not targeted at any subject discipline in particular, but are expectation to be gained from education as a whole.

A fairly recent document in this direction, taken as an example, is the Melbourne Declaration on Educational Goals for Young Australians, (2008), which sees:

(a) successful learners as students who:	
(i)	develop their capacity to learn and play an active role in their own learning;
(ii)	have the essential skills in literacy and numeracy and are creative and productive users of technology, especially ICT, as a foundation for success in all learning areas;
(iii)	are able to think deeply and logically, and obtain and evaluate evidence in a disciplined way as the result of studying fundamental disciplines;
(iv)	are creative, innovative and resourceful, and are able to solve problems in ways that draw upon a range of learning areas and disciplines;
(v)	are able to plan activities independently, collaborate, work in teams and communicate ideas;
(vi)	are able to make sense of their world and think about how things have become the way they are;
(vii)	are on a pathway towards continued success in further education, training or employment, and acquire the skills to make informed learning and employment decisions throughout their lives;
(viii)	are motivated to reach their full potential.

(b) confident and creative individuals as students who:	
(i)	have a sense of self-worth, self-awareness and personal identity that enables them to manage their emotional, mental, spiritual and physical well-being – have a sense of optimism about their lives and the future;
(ii)	are enterprising, show initiative and use their creative abilities;
(iii)	develop personal values and attributes such as honesty, resilience, empathy and respect for others;
(iv)	have the knowledge, skills, understanding and values to establish and maintain healthy, satisfying lives;
(v)	have the confidence and capability to pursue university or post-secondary vocational qualifications leading to rewarding and productive employment;
(vi)	relate well to others and form and maintain healthy relationships;
(vii)	are well prepared for their potential life roles as family, community and workforce members;
(viii)	embrace opportunities, make rational and informed decisions about their own lives and accept responsibility for their own actions.

(c) active and informed citizens as students who:	
(i)	act with moral and ethical integrity;
(ii)	appreciate Australia's social, cultural, linguistic and religious diversity, and have an understanding of Australia's system of government, history and culture;
(iii)	understand and acknowledge the value of Indigenous cultures and possess the knowledge, skills and understanding to contribute to, and benefit from, reconciliation between Indigenous and non-Indigenous Australians;
(iv)	are committed to national values of democracy, equity and justice, and participate in Australia's civic life;
(v)	are able to relate to and communicate across cultures, especially the cultures and countries of Asia;

(vi)	work for the common good, in particular sustaining and improving natural and social environments;
(vii)	are responsible global and local citizens.

These expectations refer to education as a whole and not specifically to science education. Nevertheless, it must surely be recognised that, in the current climate of education being delivered through subject domains, these attributes are expected to be developed through all subject areas. This indicates science education is expected to play an important role in all such developments. This is an important argument. Dismissed is any notion that specific subject disciplines account for a sub-set of specific goals only – the viewpoint that subjects have different education goals must be dismissed, especially if there is any element of choice in the educational provision offered to students.

Section (a) sets out mainly cognitive expectations, which are expected to be found in virtually any science curricula worldwide. These expectations within science education aims can be expressed in terms, such as: to develop a capacity to learn, to think scientifically and make sense of their world, to solve scientific problems though planning, collaborating and communicating thus preparing for lifelong learning and to develop aspirations to reach their true potential. While these do not point to any specific science content learning, they recognise the need to relate the learning to the *world of the learner* and recognise that learning in school should not be the end of scientific development.

Section (b) relates to the personal domain. This also can be expected to include important aspects of learning in science disciplines, even though many curricula may not explicitly recognize this. Developing a personal identity and to develop self actualization, self efficacy and clearly self worth are surely important personal developmental attributes. Studies in science subjects, in striving towards motivation of students, can be expected to pay much attention to these aspects. Also important are personal values attributes, where the science education provision could encompass terms not mentioned above, such as perseverance, ingenuity, safe working for oneself and for others, and a willingness to participate. These important personal attributes preparing for potential life roles are often neglected in science teaching. They draw attention to the need to develop life skills, where abilities gained in science lessons can be building blocks for capabilities in life beyond school.

Section (c) draws attention to the moral and ethical importance of teaching and the need to pay attention to this in the science classroom. Science teaching, in playing its role in framing future citizens for moral and ethic integrity, can help students to appreciate the values in the way of life built up by the society in which the students live. With many issues in society having socio-scientific roots, it is important that values education plays a strong role in science teaching. Learning to work for the common good, rather than individual isolationism, can be a particularly strong teaching component. This is promoted through teamwork in science activities and through participation in scientific discussions, reasoned socio-scientific decision-making and in striving for consensus.

A Paradigm Shift in Science Education expectations

If science education is to truly relate to the overall education provision within a country, it is proposed there is a need for a paradigm shift in the view of science education within this education provision. If the goals of education are to be truly met, then teaching within science lessons must focus on playing an essential part. For this, it is important to recognize that science education must be considered in three key areas - intellectual development, personal attribute development and social values development. Such a paradigm shift identifies the goals of education and the goals of science education as being one and the same. Science education does not put forward additional goals of its own, but operates within the overall education frame and strives (*and this is the hard part*) for a balanced curriculum with regard to the goals of education. This in essence means – science education cannot simply be about science content acquisition.

A Reformulated View of the Nature of Science Education

If the goals of education and the goals of science education are to be appreciated as being the same, the question arises what role is expected of science education in meeting these goals? In fact, why is science education expected to be an important entity within the curriculum?

Education cannot be developed in a vacuum. It needs a context and this context, inevitably in science lessons, involves science content and science conceptual learning. Thus, although science content need not be specified and may be related to a contemporary context, science lessons utilise the acquisition of scientific ideas to aspire to playing their major role in the development of students through an appropriate context. Unfortunately, the more emphasis is placed on the content, the more the purpose of science education (in terms of the overall goals of education) become hidden, an aspect that is poorly recognised by external examination boards who have been masters at promoting this unbalanced deception. And even more unfortunate, many science curricula and science textbooks, in framing a logical sequence, also take content as the frame of reference. Not surprising therefore, within school science learning, there is an expectation that the major target is content acquisition and the consequence is that insufficient attention is paid to the 'real' education – striving towards the goals of education and in so doing preparing students for the world beyond the school.

The 'true' nature of science education puts the learning of the nature of science into an educational framework. It links the nature of science with the full spectrum of educational goals described earlier under the domains of personal and society developments. With this in mind, it is proposed that the aim of science subjects is providing meaningful education through acquiring an understanding of the nature of science (NOS) in meaningful social contexts, linked to gaining personal and social abilities through student directed approaches such as inquiry-based teaching and problem solving investigations. And this leads to an important need to consider the implication of recognising learning in the area of the nature of science (NOS) (Bell & Lederman, 2003; El-Khalick, & Lederman, 2000).

Where factual memorisation and teacher-structured learning (whether wholly teacher centred, or including ‘recipe-type’ student experimentation) are the main transmission modes in science classrooms, the education provision becomes distorted and the nature of science is poorly addressed. A factual approach is very likely to see scientific information as the ‘truth’, lacking any degree of tentativeness and not appreciated as being the best understanding we currently have, but subject to change in the light of new evidence. Poor science teaching, over-emphasising scientific ideas as proven fact, is also in danger or portraying a false image of the manner in which science progresses. In such approaches, science education is likely to align itself to science knowledge, being undertaken only by students wising to become scientists. Science is presented, as usually culturally free, as following a specific approach (‘the’ scientific method), based on careful observation and gaining evidence in which all other variables are rigidly controlled. It is likely to develop an impression that creativity or imagination do not play a part in the development of science ideas and that scientific laws are moving along the path (when more verification is made available) to being established as a scientific theory, expressing the irrefutable truth. In such a vision, it is unclear what is meant by social science, but probably this is seen as just another term for social studies and dismissed as unscientific.

If science is to play an important role within society, it is necessary to appreciate its place within society and its value in developing skills of socio-scientific decision making in life beyond school. Building up a picture of the nature of what is science is thus put forward as an important aspect of science teaching. The nature of science (NOS), whether from an historical and philosophical approach, or through socio-scientific issues within contemporary society, is seen as an important contribution in the attainment of the goals of education (Holbrook & Rannikmae, 2007). It is put forward as the science focus within science education, in place of a concentration on specific science content, or the need for so-called ‘fundamental or essential’ science concepts, derived from a build-up of science content linked to socially absent, science structured concept maps.

In putting forward this model for the nature of science education (NSE), the acquisition of the “big” ideas in science is relegated to building a concept of the nature of science (NOS) and/or the promoting of personal intellectual thinking. The so-called building blocks of science, or the “big” ideas as expounded by AAAS (1993) and NRC (1996), are not seen as ‘fundamental and crucial elements’ for scientific literacy. Rather, ‘basic’ knowledge is suggested as liable to regional variations and best included on a need-to-know basis (where the need for such knowledge has previously been identified). This means that the logic associated with the development of school science curricula need not be based on so-called scientific “fundamental” ideas. Rather, complex issues and situations within society, the so called socio-scientific issues (Sadler and Zeidler, 2005; Zeidler et al, 2005) can be seen as more relevant in the eyes of students as the starting points for science learning and the ‘gateway’ to the learning of scientific ideas. This allows personal and social components of learning to play a relevant and motivational role in the enhancement of scientific literacy among students. And leading on from this, it is proposed that further teaching of science subjects is through context-based situations and not through the identification of content (much of which tends to be irrelevant for today’s society).

Such a view represents a major change of focus for the teaching of science subjects and suggests that *no content* is fundamental. It, of course, cannot, nor does it, exclude science content, but recognizes that the content needed for enhancing scientific literacy is dependent on the culture and societal in which the science education is being implemented. This, it is claimed, is true even noting the current spread of globalization and the increased mobility of people across cultural divides. This view of science education suggests that, where there is a need for science knowledge, this need relates to a moving platform within society. The concerns and the future responsibilities of citizens in the workplace, or in the society itself, are subject to change.

The key driving force for this view of the NSE is the need for students to acquire social skills, supported by individual skills, thus enabling students (and later as adults – Roth and Lee, 2004) to play a responsible role within society in terms of

(a) developing social values such that a person can act in a responsible manner within the community, system, nation or, as in the school situation, at a smaller group level;
(b) being able to function within the world of work whatever the skill or responsibility level;
(c) possessing the conceptual background and skills of learning to cope with a need-to-have, relevant public understanding of science and technology in a changing society.

In fact, developing personal attributes, social attributes and a suitable conceptual background, geared to an appreciation of the actual nature of science, are the essence of enhancing true (Shamos, 1995) or multi-dimensional (Bybee, 1997) scientific literacy.

Viewing Science Education as 'Education through Science'

As mentioned in an earlier version of the journal (December 2009) science content is not the only learning undertaken by students in the science classroom. Students are being educated above and beyond the content domain and really therefore science education needs to be considered from an educational perspective. Education is the real area of focus for science teachers and science as subject matter is just one aspect, albeit an important aspect, of the learning. The term 'education through science' is thus proposed to express the intentions for the teaching-learning approach, geared to NSE advocated in this article. This suggests NSE puts emphasis on relating the learning in science lessons to society needs and to gaining an appreciation of the nature of science from a societal point of view. NSE also encompasses learning in areas such as creativity, problem solving as well as safe working, risk assessment and attributes such as perseverance, ingenuity and working as a member of a team. The ultimate goal is that the education enables a person to function with society as a responsible citizen, able to incorporate science understanding into decision making activities and to appreciate the value of science in today's society.

'Education through science' expresses a view that schools are expected to play a role in developing student capabilities for the future, no matter what career direction, what higher education emphasis, or what role students play within society as future citizens. 'Education through science' thus stands alongside education through other, non-science, school disciplines enabling students to be recipients of an appropriate provision to acquire the stipulated goals of education.

Conclusion

Gaining a clear conception of NSE is important for the way science subjects are portrayed and taught in school. NSE is, of course, governed by the curriculum, and especially the stated overall goals of education, but is currently being poorly expressed in relation to these overall goals. Unless teachers have a clear idea of NSE, it is unlikely they can fulfill the demands of society in implementing the education intended.

There is a need to move away from a content-led teaching direction to one that focusses on the needs and motives of students for learning through science subjects. This can be expressed as society-focussed, socio-scientific issues led (Zeidler & Keffer, 2003), or 'education through science', where the science is the important vehicle for learning. Examples of such science teaching do exist and the ideas indicated in the PARSEL project (www.parsel.eu), in which ICASE was involved, are put forward as worthy of serious consideration.

What is not explicitly expressed by NSE and will always be dependent on a variety of factors, is the emphasis to be given in science education to each of the educational domains and the classoom atmosphere in which the teaching approach is motivational for students.

As Osborne, Simon and Collins (2003) point out:

> *'a clear feature of science education research is the decline in attitudes towards science from age 11 onwards. This is documented by a number of studies which all show how children's interest and attitude to science declines from the point of entry to secondary school. The evidence would suggest that children enter secondary school/junior high with a highly favourable attitude towards science and interest in science, both of which are eroded by their experience of school science, particularly for girls."*

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