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The Nature of Science Education for enhancing Scientific Literacy

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Abstract

This article explores the meaning of the nature of science education to enhance scientific literacy. It argues that the teaching approach for science education should be regarded as “education through science, rather than “science through education”. A model of the nature of science education is proposed having its foundations based on activity theory rather than logical positivism. This encompasses an understanding of the nature of science, with links to achievement of goals in the personal domain, stressing intellectual and communication skill development, as well as the promotion of character and positive attitudes, plus achievement of goals in the social education domain, stressing cooperative learning and socio-scientific decision making. Although the nature of science is seen as an important component of science education, the over-riding target for science teaching in school, as an aspect of relevant education, is seen as responsible citizenry, based on enhancing scientific and technological literacy. The meaning of scientific and technological literacy is discussed.

Key words – nature of science education, nature of science, education through science, true or multi-dimensional scientific and technological literacy, relevant education, activity theory.

Introduction

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 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 thorough basic understanding of fundamental content knowledge (AAAS, 1993; NRC, 1996).

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A model is put forward for the nature of science education which is based on educational needs, as determined by the curriculum, and leads to an approach through which “education through science” is perceived as a more appropriate description of the teaching emphasis than science through education. Teaching based on this model is less about post positivism or constructivist approaches and more related to activity theory (Roth and Lee, 2004; van Allsvort, 2004a; 2004b) where student needs and student motivation, and hence interest, form the major focus. The encompassing teaching framework is thus one of increasing the relevance of science education (Fensham, 2004) in the school situation from both an educational and societal perspective.

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2 This paper recognises that the ideas proposed are really applicable to secondary (beyond grade
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4 6) more than primary education. It accepts that at the primary education level student interest
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6 in science is generally positive and, at that level, science, reflected as investigational science,
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8 can bring great enjoyment to students as they explore, in a concrete manner, many scientific
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10 ideas. As Osborne, Simon and Collins (2003) point out:

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14 'a clear feature of science education research is the decline in attitudes towards science
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16 from age 11 onwards. This is documented by a number of studies which all show how
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18 children's interest and attitude to science declines from the point of entry to secondary
19
20 school. The evidence would suggest that children enter secondary school/junior high with
21
22 a highly favourable attitude towards science and interest in science, both of which are
23
24 eroded by their experience of school science, particularly for girls (Kahle and Lakes,
25
26 1983). Such findings need to be qualified by the rider that other research shows that
27
28 attitudes to all subjects decline in general during adolescence (Eccles and Wigfield, 1992;
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30 Epstein and McPartland, 1976)'

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32
33 It is with the need to further develop reasoning skills and to draw conclusions (Sadler 2004;
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35 Sadler and Zeidler, 2005), to guide students to develop argumentation skills (Driver,
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37 Newton & Osborne, 2000; Osborne, Erduran & Simon, 2004) and to make judgemental
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39 decisions utilising scientific ideas (Ratcliffe, 1997; Kortland, 2001) that science education
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41 becomes problematic and there is the danger that an over-emphasis on content
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43 overshadows acquisition of educational goals and thus inhibits the promotion of multi-
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45 dimensional levels of scientific literacy (Bybee, 1997) for functioning within society.

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2 Science education, at the secondary level (grade 7 and above), is firmly included as a
3 component of the education provision virtually worldwide. In most curricula, and through
4 perceptions held by the majority of teachers, science education is seen as building on logical
5 positivism ideas (van Aalsvoort, 2004a) in propogating scientific information and concepts as a
6 theoretical component on the one hand and an observational language on the other. This
7 implies that science teaching is seen as relating to the observation of phenomena which are
8 then generalised into theories and these theories supported by further observation. There is a
9 cycle of teaching, often promoted as hypothetico-deductive, which calls for observations to be
10 generalised into well known laws or theories and for laws and theories to be supported by
11 carrying out observations. The theoretical ideas underpinning this are thus about the rationality
12 of results already existing, rather than new discoveries. As suggested by van Aalsvorst (2004a),
13 such a theoretical underpinning inhibits rather than promotes relevancy of science teaching in
14 the eyes of students. The science teaching focus is from an understanding of what is important
15 from a scientist's perspective rather than from the viewpoint of the learner, or society. It calls
16 upon students to act as 'little scientists', even though they have yet to master the problem
17 solving and decision making skills which are an integral part of their science learning. This
18 focus can be summarised as shown in table 1. Such an approach is not advocated in this paper,
19 nor seen as the substance for promoting meaningful scientific literacy.

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37 Table 1 about here

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39 Besides the decline in student attitudes towards science (Osborne et all, 2003), an appropriate
40 teacher understanding of the nature of science education is likely to be suspect and linked to
41 this, the manner in which science teaching includes understanding of the nature of science
42 (Lederman, Wade & Bell, 1998). While there is no universal conceptualisation of the nature of
43 science (Kang et al., 2005; Scharmann & Smith, 2001) and as Suchting (1995) has argued,
44 views on the nature of science are likely to evolve as science grows, there does seem to be
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2 broad general agreement that the nature of science should be recognised as a human endeavour
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4 (the human fallibility has been limited, but not entirely eliminated), tentative (subject to
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6 change, as the knowledge is not proven, but simply not falsified), empirical (based on and/or
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8 derived from observations of the natural world although these are theory-laden), include human
9
10 inference (as distinct from observation), imagination, and creativity (putting forward
11
12 explanations), and be socially and culturally embedded (Lederman et al. 1998; Hand et al.,
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14 1999; Bell and Lederman, 2003; Schwartz et al., 2004; Abd El Khalick, 2005; Kang et al.,
15
16 [2005](#)). The fact that observation and experiment are the only basis on which science is built
17
18 lends support to rational activity constituting knowledge claims through argumentation, but
19
20 does not eliminate the human or social aspects and goes some way to suggesting why studies in
21
22 areas such as sociology, economics and civics can be considered as a science under the heading
23
24 of social science.
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27 **The Nature of Science Education**

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29 In most educational systems, science education is an integral part of the total education
30
31 provision within a school. It may be argued that different subjects should cover different
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33 educational domains, or perhaps sub-domains [\(for example, language subjects covering the](#)
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35 [development of communication skill; mathematics used to teach logic; social science covering](#)
36
37 [the teaching of cooperative learning or social values and science teaching psychomotor and](#)
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39 [problem solving skills\)](#), but this cannot be realistic, given that choice of subjects within the
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41 curriculum is often practiced. Assuming the education provision needs to be covered across the
42
43 range of educational skills in the combination of subjects selected by students, it therefore
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45 seems logical that all subjects taught need to relate to the full spectrum of educational goals.
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47 By recognising that science education is part of the education provision within schools, the
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49 teaching of science subjects can be expected to promote the development of a range of skills
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2 and values, identified within the educational goals and especially to enable students to solve
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4 problems, in this case, of a scientific nature and make appropriate socio-subject decisions, in
5
6 this case socio-scientific (Holbrook & Rannikmäe, 2002). The nature of science education is
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8 thus far more than an understanding of the nature of science.
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11 In the past, the domains of education were sub-divided into cognitive, affective and
12
13 psychomotor (Bloom, 1956), especially when considering the teaching of science subjects. The
14
15 cognitive domain included the development of thinking skills and could also be said to include
16
17 problem solving skills and reasoning abilities. However, creativity in an artistic sense, interest,
18
19 personal development and various forms of dexterity applied in an appropriate context (e.g.
20
21 practical work) are related to the affective and psychomotor domains. Today, however, a wider
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23 view of educational components are more likely and ~~cover intellectual, communicative, social~~
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25 and moral, cooperative, personal and physical skills, as well as attitudes (Curriculum
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27 Development Council, 1995).
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32 The Bloom categorisation of educational goals into cognitive, affective and psychomotor
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34 components has not been empirically derived from the way students learn, but rather from
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36 opinions by educators (Biggs, 1996). However, while other taxonomies, such as SOLO (Biggs,
37
38 1996) derive from observed student learning outcomes, they do not match the education goals
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40 as specified in curricula. Where these goals cover intellectual and communicative skills,
41
42 together with personal development and attitudes, these can be considered as components of an
43
44 individual, or personal, domain. They all pertain to the development of the individual. On the
45
46 other hand, cooperative learning, which obviously takes place in a group and social, ethical and
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48 moral values relating to interactions and decision making within society, can be taken as
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50 components of a society domain. This condensation allows the sub-divisions of educational
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2 goals to be regrouped into three revised components - a Personal domain, a Society domain,
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4 plus a domain geared to attributes of the subject. For science, it is proposed that the attributes
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6 of the subject are provided through acquiring an understanding of the Nature of Science in
7
8 meaningful contexts, linked to enquiry teaching and problem solving investigations.
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11 The Nature of Science Education can thus be perceived as a 3 domain representation, as
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13 illustrated in figure 1:

14
15 Figure 1 about here

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17 From this figure, the nature of science education is clearly portrayed as more than an Deleted: that
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19 understanding the nature of science, or acquisition of scientific ideas. The nature of science
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21 education puts the learning of the nature of science into an educational framework. It links the
22
23 nature of science with the full spectrum of educational goals described earlier under the
24
25 domains of personal and society developments. This is proposed as a major change of focus
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27 for classroom implementation and also for the assessment of student achievements in the
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29 discipline of science education. It suggests the teaching of science subjects is through a 3
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31 domain educational structure, not simply through science content and such a structure forms
32
33 the focus for the enhancement of scientific literacy through formal schooling.
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37 In putting forward this model for the nature of science education, the acquisition of the “big”
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39 ideas in science has been relegated to building a concept of the nature of science and/or the Deleted: ve
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41 promoting of personal intellectual thinking. The fundamental building blocks of science by
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43 themselves, or the “big” ideas as expounded by AAAS (1993) and NRC (1996), are not seen as
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45 crucial elements of scientific literacy. This does not mean they are excluded from the teaching
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47 of science, but it is a recognition that useful basic knowledge is tentative, liable to regional
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49 variations and best included on a need-to-know basis (where the need for knowledge has
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previously been identified). This will mean that the curriculum logic based on the
“fundamental” ideas no longer forms the basis for teaching. Rather complex issues and
situations within society, the so called socio-scientific issues (Sadler and Zeidler, 2005; Zeidler
et al, 2005) are seen as the starting points for science learning. 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 the teaching of
science subjects is through context based situations and not through the identification of
essential content. Such a view represents a major change of focus for the teaching of science
subjects and suggests that no content is fundamental, but rather 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.

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The key driving force for the nature of science education 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

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(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 at whatever the skill or responsibility
level;
(c) possessing the conceptual background or skills of learning to learn to cope with a need-
to-have, relevant public understanding of science and technology in a changing society.

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These are the essence of enhancing true (Shamos, 1995) or multi-dimensional (Bybee, 1997)
scientific literacy.

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Education through Science

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2 Teachers are educators. Education is the area of focus for science teachers and the science is
3 merely the vehicle for this. The term 'education through science' is proposed to express the
4 intentions for the teaching-learning approach geared to the nature of science education
5
6 [advocated in this article](#). The [proposed](#) nature of science education is thus not about stressing
7
8 the ways of the scientist any more than history is taught for students to become historians, or
9
10 language is taught to become linguists. It is proposed that science in school is part of the
11
12 education provision and any science content is gained so as to enhance that education in the
13
14 nature of the subject, the personal or the social domains. Table 2 below illustrates a comparison
15
16 of 'education through science' with 'science through education' – the alternative if in the short
17
18 term, nature of science, or a content approach to science teaching, is the sole basis for the
19
20 nature of science education proposed.
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23 Table 2 about here

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25 While the inclusion of personal and society domains into the learning structure are expected to
26
27 enhance the relevance of science teaching, the approach is not explicit and the need for a
28
29 stronger theoretical construct is needed. This is provided by activity theory.
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32 33 **The Nature of Science Education and Activity Theory**

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35 In recognising the trend towards education through science, van Aalsvoort (2004b) proposes
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37 activity theory to replace logical positivism as the tool to address the lack of relevance of
38
39 school science. This approach is strongly reinforced by Roth and Lee (2004). The theory is
40
41 based on [the interlinking of knowledge and social practice through](#) establishing a need
42
43 (relevant in the eyes of students), identifying the motives ([wanting](#) to solve scientific problems
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45 and make socio-scientific decisions) leading to activity constituted by actions (learning in
46
47 school towards becoming a [scientifically literate](#), responsible citizen). The activity model is
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49 appropriate for [realising](#) the goals of education, although van Aalsvoort's [examples](#) do not
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attempt inclusion of the personal and social domains of education. Hjs examples, although
 society related, are subject specific and do not involve socio-scientific decision making, linked
 to the reflection stage directly (the decision are scientifically oriented and do not dwell, for
example, on environmental, economic or ethical factors). On the other hand, Roth and Lee
 (2004) see activity theory forming a theoretical base for developing scientific literacy
integrating the society need and the interrelated subject need. They postulate that activity
 theory is particularly appropriate for theorising participation and learning across multiple,
 heterogeneous settings (Chaiklin & Lave, 1993; Engestr'om, Miettinen & Punam'aki, 1999).

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In activity theory, activities constitute the unit of analysis (Roth and Lee, 2004). The basis of
 the activity theory revolves around three levels of activity (van Aalsvoort, 2004b), namely

1. the level of activity proper,
2. the level of actions, and
3. the level of operations.

Besides this, the development of an activity and a recognition of the role of scientific concepts
 depends on reflection as this important step allows evaluation of the activity and its results.

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The level of an activity proper can be interpreted as science-related social practices (van
 Aalsvoort, 2000). Such practices are meant to provide for student needs (as perceived by
 students insofar as this is possible, otherwise perceived by society as an area of need) in a more
 or less organized way by making 'products' or 'decisions' from 'raw materials', scientific
 components, or issues to resolve. The activity can be 'enquiry process' or 'debate'. These
 practices may be characterized by a number of motives, because scientific problem solving
results from wanting to determine a solution which, in turn, can feed a decision making process
linked to the students' need for resolving a social issue, van Aalsvoort (2004b) used the need

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2 [for water as the issue of social concern, the production of drinking water from suitable raw](#)
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4 [materials as the problem solving component and centred the decision making on the type of](#)
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6 [waterworks to design.](#)
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10 At the level of actions, the division of labour is the usual social practice and cooperative
11 learning within groups is the usual action within the classroom. The motive [\(wanting to decide\)](#)
12 or [the goal \(learning to decide\)](#) relates to [deciding](#) the best choice, taking into consideration the
13 needs of all members of the society.
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19 Operations concern the techniques and routines that are characteristic for the carrying out of
20 the actions. In the classroom, these involve the plans and procedures for problem solving, but
21 in society they can involve experts in experimental procedures, or [ways for](#) the presentation of
22 [outcomes.](#)
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27 *“For example, articles and reports have a certain arrangement, and talks are given*
28 *according to certain conventions. The techniques and routines, which are to be used,*
29 *depend on objective circumstances, for instance, the availability of apparatus, the*
30 *properties of [substances chosen](#), scientific requirements with respect to experimental*
31 *procedures — cultural conditions for short. It is important to notice that cultural*
32 *conditions are not unchangeable, but that they change over time. Moreover, they are*
33 *often the outcome of other social practices. A telling example is the availability of*
34 *apparatus mentioned earlier.” [\(van Aalsvoort, 2004b\)](#)*

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Reflection

In the framework of science-related practices, reflection has the function of bringing about improvements in a practice, or a decision. These may concern the quality of products,

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2 processes to be used, or the choices to be made. Reflection takes place using, among others,
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4 science concepts as tools.
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8 Reflection plays an important role in learning according to activity theory. This holds for
9
10 practice as well as decisions made. Reflection can take the shape of planning a course of
11
12 action, justifying what one is planning to do or has done, and comparing two courses of action.
13

14 It should be noted that, according to a sociocultural approach, reflection does not happen in the
15
16 mind of an individual only. Rather, reflection takes place when people cooperate on a task. In
17
18 this, language is a tool that creates the possibility of thinking and organizing thought processes.
19

20 In the example by van Aalsvoort (2004b), reflection is geared to reasons put forward for the
21
22 choice of raw materials for the production of drinking water and, later, reflection looks back at
23
24 any problems associated with the purification process chosen.
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26 27 *The learner*

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29 In this approach, it is interesting to note that the learner is considered an apprentice. This is to
30
31 say that the learner participates in a practice, although at first, participation takes place in a
32
33 school version of the practice. An apprentice cannot be expected to carry out tasks in a
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35 professional way. Again van Aalsvoort (2004b) illustrates this by the use of coloured water,
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37 rather than the more realistic water containing pesticides, in the purification of water, allowing
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39 students to be guided to take on the role of chemical analysts more safely in determining
40
41 whether the purified water prepared meets the requirements of the law.
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44 Activity theory, therefore, assumes that social practices develop due to interplay between the
45
46 above practices. For this science education needs to involve students in identifying and
47
48 carrying out activities related to their needs (or the needs perceived by society which are
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1
2 relevant to student learning). In the classroom, addressing the need are not driven by
3 considerations of completing a curriculum or preparation for an examination, but heavily
4 related to relevance in an educational sense. Roth and Lee (2004) likened the activity theory to
5 a rope with threads and fibres. The community of practice or the society are represented by the
6 rope; the persons involved are the threads, and the various knowledge and skills held by the
7 individuals are the fibres.
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13 14 15 16 **Meaning of Scientific and Technological Literacy (STL)**

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18 As indicated in the introduction, the teaching of science in school is taken to be the enhancing
19 of scientific literacy. The nature of science education is such that it provides the framework for
20 formal education to focus in this direction. It is now time to try to clarify the meaning of
21 scientific literacy. As a start, noting that developments within society are largely of a
22 technological nature, it is proposed that it is more appropriate to consider scientific and
23 technological literacy when referring to education through science (UNESCO, 1993). In the
24 school context, it is extremely difficult to distinguish between scientific literacy and
25 technological literacy, as the two go together (technology is not intended to simply refer to
26 computers, or the simple acquisition of technical skills, but to the man-made materials and
27 processes developed within society). In fact, for all practical purposes related to the teaching
28 within schools, scientific literacy and technological literacy can be taken to be the same. This
29 does not mean that science is the same as technology, far from it. But it does suggest that the
30 conceptual knowledge, personal and society values inherent in the development of STL in this
31 sense are indistinguishable. The only difference in the teaching of science and the teaching of
32 technology is in the nature of science, as opposed to the nature of technology.
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2 While communication skill is a crucial component of literacy - referred to as literacy in its
3 fundamental sense, rather than a derived sense, by Norris and Phillips (2003) - it is difficult to
4 see how any approach to STL is bound simply by language, or by a dominance of the written
5 text. Language ability, as a component of communication skill, is itself part of the personal
6 domain in the model for the nature of science education detailed earlier and is thus common to
7 learning in all subject areas, not just science education. Scientific and technological literacy is
8 much more than language proficiency, as the French translation of scientific and technological
9 literacy as “culture scientifique et technologique,” (UNESCO 1994) strongly suggests.

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20 The foundation of STL inevitably relates to the conceptualisation of need-to-know scientific
21 knowledge, although many school curricula seem to place higher emphasis on developing a far
22 wider knowledge component than is warranted for a subject area expanding at a faster and
23 faster pace (Schibeci & Lee, 2003). Knowledge for its own sake, and hence communication
24 linked to such knowledge (Norris and Phillips, 2003), needs to give way to knowledge and
25 communication for functionality in society and this is likely to be culturally and even
26 regionally bound.
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35 STL is expected to indicate an ability to function, or the potentiality to function, within society
36 (Kolsto,2000, Millar,1996) This can cover an understanding of the science underpinning the
37 technological advances of today, but that is a gigantic undertaking and beyond the ability of any
38 one person (Shamos, 1995). Global understanding of science in society cannot be seen as a
39 target for school science education. Rather STL is related to an awareness of the science within
40 society and an awareness of experts who can provide the understanding that the ordinary
41 citizen may lack (Shamos, 1995, DeBoer, 2000). But that still does not cover the enabling of
42 decisions to be made in a democratic society, where science driven technology is playing a
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2 greater and greater role. Nor does it develop an appreciation that the advantages of
3 technological developments can be great for some, but a major disadvantage for others and
4 where side-effects related to health, the sustainability of the environment, or economic
5 concerns can become key factors in choosing the most appropriate science-driven technology
6 (Roth and Lee, 2004; Sadler and Zeidler, 2005). STL is seen as embracing all of this.
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14 STL is a simple term and its major advantage is that it can be used to sum up, at the school
15 level, the intentions of science education (AAAS, 1989; NRC, 1996) and highlight the nature
16 of science education needed. It avoids the use of distracting detail and, as such, convincingly
17 portrays a complex idea which intuitively appears to be correct (Baumert, 1997). But it suffers
18 from two divergent visions:
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24 a) those who advocate a dominant role for specific ideas in science, promoted within
25 an understanding of the nature of science (AAS, 1993; NRC, 1996) and. hence
26 focus the nature of science education on an understanding of the science within
27 society;
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30
31 b) those who see the nature of science education predominantly linked to promoting
32 the functionality of a citizen within society (Roth and Lee, 2004).
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36 The first camp seems to be very prevalent among science teachers today. It builds on the
37 notion that there are fundamental ideas in science which are essential and that this is required
38 in building a concept of the nature of science. The nature of science education is dominated by
39 the conceptual science component and scant attention is focussed on personal and social
40 aspects. A science dominant nature of science education has been described as a short term
41 view (Maienschein, 1998) and even labelled as “science literacy” to distinguish it from a
42 longer term view of “scientific literacy”.
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2 The second vision sees STL as a requirement to be able to adapt to, and play a responsible role
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4 in, the challenges of a rapidly changing world. It recognises the need for reasoning skills in a
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6 social context which are based on sound scientific ideas, derived from conceptual
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8 understanding and linked to the nature of science. And above all, this view recognises that STL
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10 is for all (Roth and Lee, 2004) and has little to do with science teaching solely focusing on a
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12 career in science, or solely providing an academic science background for specialisation in
13
14 science. This second view essentially refutes the need for two types of school science courses –
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16 one for general education and another for specialists – and recognises that a specialist course
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18 would simply be an extension of the former with an increase of “time on task” - that is, more
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20 science lessons (Holbrook, 1998). This direction sees responsible citizenry as a major focus, in
21
22 which scientific knowledge is used wisely for the benefit of society. Roth and Lee (2004) and
23
24 others (Jenkins, 1999) have called this citizen science. It strongly includes the personal and
25
26 social domains alongside the nature of science. And while its teaching is in the context of
27
28 education through science and is issue-based or context-based (Zeidler et al., 2005), the
29
30 scientific ideas are limited to the issue in hand, However it does not eliminate the inclusion of a
31
32 historical perspective, nor exclude teacher knowledge inputs alongside student constructivist
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34 learning.

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36 “School science education needs to respond to a changed social context and to help
37
38 prepare young people to contribute as citizens to shaping the world in which they will
39
40 live“ (Jenkins, 1999).

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43 To succeed leads to a well informed, responsible citizenry in the future. To get [the provision of](#)
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45 [appropriate school science](#), wrong, and indicators suggest this is the current situation (European
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47 Commission, 2004), leads to irrelevant curricula, an unpopular subject and a lack of student
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49 interest. Where high stakes, pencil and paper, summative examinations are the sole assessment
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2 measures, the assessment of the real nature of science education and hence the relevance of
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4 school science is always likely to be in danger, as personal and social learning is omitted from
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6 the assessment and most probably from implementation in the classroom.. In such a situation, it
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8 is difficult to perceive how this can detract from the current unpopularity of the subject
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10 (European Commission, 2004). Nor will such summative assessment, necessarily lead to a
11
12 better informed society capable of making decisions.

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16 It is thus proposed that the trend in defining STL is away from the short term scientific
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18 knowledge as a product approach, in which the facts and skills are paramount, towards

- 19 Deleted:
- 20 (a) inclusion of issue-based or context-based teaching as a major thrust to 'set up' the
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22 scientific problem to be investigated (Zeidler et al, 2005);
- 23
24 (b) the need to go beyond scientific problem solving (related to appreciating the nature of
25
26 science and through enquiry, acquiring relevant process skills) to also encompass socio-
27
28 scientific decision making (related to responsible citizenry and public understanding of
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30 science even if this is related to the public understanding of science),
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32 (c) recognition that scientific literacy relates primarily to enabling citizens to effectively
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34 participate in the real world and is thus a social rather than an individual consideration
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36 (Roth and Lee, 2004).

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38 A single, simple definition of STL or scientific literacy building on the model of the nature of
39
40 science education as expounded is always likely to be extremely problematic. The OECD
41
42 (2003) PISA study suggested:

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44 *“the capacity to use scientific knowledge, to identify questions and to draw evidence-*
45
46 *based conclusions in order to understand and help make decisions about the natural*
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48 *world and the changes made to it through human activity”.*
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2 The emphases on drawing conclusions and decision making suggest an understanding of the
3 nature of science and the inclusion of a social domain are key components in their ideas of the
4 nature of science education. Developing the capacity to use scientific knowledge also indicates
5 the development of intellectual skills of the person and points to the nature of science
6 education encompassing a personal domain.
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12 The inclusion of a social and personal domain concept of scientific literacy also comes through
13 from the ICASE-UNESCO forum on scientific and technological literacy for all (UNESCO,
14 1993), which suggested scientific literacy as:
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19 *“the capability to function with understanding and confidence, and at appropriate*
20 *levels, in ways that bring about empowerment in the man-made world and in the*
21 *world of scientific and technological ideas”.*
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26 A later definition by ICASE, intended to involve the nature of science, the personal and the
27 social domains, but also stressing socio-scientific decision making, is (Holbrook and
28 Rannikmae, 1997):
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33 *“developing the ability to creatively utilise sound science knowledge in everyday life, or*
34 *in a career, to solve problems, make decisions and hence improve the quality of life”.*
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38 **Conclusion**

39 Appreciation the nature of science education is important for the way science subjects are
40 portrayed and taught in school . The nature of science education is, of course, governed by the
41 curriculum, and especially the stated overall goals of education, but is currently being poorly
42 expressed in relation to these overall goals. Unless teachers have a clear idea of the nature of
43 science education, it is unlikely they can fulfill the demands of society in implementing the
44 education intended.
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4 Important also is the focus of science education if it is to enhance students' acquisition of
5 scientific and technological literacy as expressed by Shamos (1995) and Bybee (1997) . There
6 is a need to move away from a content led teaching direction to one that focusses on the needs
7 and motives of students for learning through science subjects. This can be expressed as society-
8 focussed, socio-scientific issues led (Zeidler & Keffer, 2003), education through science,
9 where the science is merely the vehicle for the learning.
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18 What is not explicitly expressed by the nature of science education, and will always be
19 dependent on a variety of factors, is the emphasis to be given in science education to each of
20 the educational domains and the classroom atmosphere in which teaching is made interesting and
21 motivational for students.
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28 Developing science curricula, based on a nature of science education, in which the domains of
29 the nature of science, the personal domain and the social domain, linked to activity theory, is
30 put forward as a direction of promise. It is proposed as an approach for relevant science
31 education and the enhancement of true or multi-dimensional scientific literacy for a future
32 society.
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Table 1. Characteristics of science education when modelled on logical postivism (based on Van Allsvort, 2004a).

Teaching strategy	Implication of viewing students as scientist	Inference of science as a role model for citizens	Implication of science taking the hierarchical position compared to technology
Puts forward singular observational statements which give rise to universal observational statements or vice versa.	Students establish facts by making observations objectively.	The coming into existence of scientific results is disregarded.	Emphasis is on science knowledge rather than its applications.
Based on universal observational statements, a theory is made plausible, or vice versa.	Students thinks logically on the basis of facts.	There is no room for the development of professional skills.	Technological results or procedures are depicted as applications of science knowledge.
A theory gives rise to new universal observational statements, from which testable singular observational statements are derived.	Students does not let psychological or contextual factors influence their observations.	Logic replaces psychological, social, historical, and cultural factors.	Science knowledge precedes its applications in technology and society.
Reflects on the work of scientists.	The scientist serves as a role model.	The meaning of science concepts in	

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ready-made science is
different from their
meaning in science in
the making.

Science education Science education can
deals with ready-made be typified as the
science rather than transmitting of
science in the making. science knowledge.

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Table 2. A comparison of similarities and differences in philosophical emphases between 'Science through Education' and the alternative 'Education through Science'.

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	Undertake socio-scientific decision making related

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scientific 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.

For Peer Review Only

Figure 1 The Three Domains of Education (illustrated for science education)

