Promoting scientific literacy: science through education or education through science

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Earlier research has shown, science
- Is unpopular and irrelevant in the eyes of students (Kracjik, 2001; Osborne and Collins, 2001; Pak, 1997; Sjoberg, 2001; WCS, 1999; ICASE, 2003).
- Does not promote higher order cognitive skills (Anderson, 1992; Zoller, 1993).
- Leads to gaps between students wishes and teachers teaching (Hofstein and Mamlok, 2000; Yager and Weld, 2000; Holbrook and Rannikmae, 2002)
- Is not changing, because teachers are afraid of change and need guidance (Aikenhead, 1997; Bell, 1998; Rannikmae, 2001).

WSEC, Perth 2007
Fensham (2008)
- consider what are the education purposes that science and technology education can best provide for students as they move through the stages of schooling (p. 5);
- make the issue of personal and societal interest about science the reference point form which curriculum decisions about learning in science and technology relating to content, pedagogy and assessment are made (p. 6);

WSEC, Perth 2007
- consider mandating that science education should move progressively towards a real world 'context based' approach to the teaching and learning of school science at all levels of the school curriculum (p. 7);
- consider changing the assessment procedures, as critical curriculum factors, in ways that will encourage higher levels of learning as the intended outcomes of school science and technology (p. 8);
- consider how the intentions of the science curriculum for students' learning can be more authentically assessed, both with schools and externally, by the use of a wider variety of assessment tools (p. 9)

- Knowledge of the substantive content of science and the ability to distinguish from non-science.
- Understanding science and its applications.
- Knowledge of what counts as science.
- Independence in learning science.
- Ability to think scientifically.


- Ability to use scientific knowledge in problem solving.
- Knowledge needed for intelligent participation in science-based issues.
- Understanding the nature of science, including its relationship with culture.
- Appreciation of and comfort with science, including its wonder and curiosity.
- Knowledge of the risks and benefits of science.
- Ability to think critically about science and to deal with scientific expertise.

NSTA (1991)

**Intellectual (Higher Order Thinking Skills)**

1. Uses concepts of science and technology, as well as an informed reflection of ethical values, in solving everyday problems and making responsible decisions in everyday life, including work and leisure;
2. Locates, collects, analyse, and evaluates sources of scientific and technological information and uses these sources in solving problems, making decisions, and taking actions;
3. Distinguishes between scientific and technological evidence and personal opinion and between reliable and unreliable information;
4. Offers explanations of natural phenomena testable for their validity;
5. Applies skepticism, careful methods, logical reasoning, and creativity in investigating the observable universe;
6. Defends decisions and actions using rational argument based on evidence;
7. Analyses interactions among science, technology and society.

NSTA (1991)

**Attitudinal**

8. Displays curiosity about the natural and human-made world;
9. Values scientific research and technological problem solving;
10. Remains open to new evidence and the tentativeness of scientific/technological knowledge;
11. Engages in science/technology for excitement and possible explanations.
NSTA (1991)

- **Societal**
  - recognises that science and technology are human endeavours;
  - weighs the benefits/burdens of scientific and technological development;
  - recognises the strengths and limitations of science and technology for advancing human welfare;
  - engages in responsible personal and civic actions after weighing the possible consequences of alternative options.

- **Interdisciplinary**
  - connects science and technology to other human endeavours e.g. history, mathematics, the arts, and the humanities;
  - considers the political, economic, moral and ethical aspects of science and technology as they relate to personal and global issues.

Two views:

- those that advocate a central role for the knowledge of science (AAS,1993;NRC,1996)
- those who see scientific literacy referring to a society usefulness (Roth&Lee,2004, Sadler&Zeidler,2005)

Graberg, 2001

- What do people know?
- What do people value?
- What can people do?
Bybee (1997) levels

- Nominal (can recognise scientific terms, but does not have a clear understanding of the meaning).
- Functional (can use scientific and technological vocabulary, but usually this is only out of context as is the case for example in a school test of examination).
- Conceptual and procedural (demonstrates understanding and a relationship between concepts and can use processes with meaning) and
- Multidimensional (not only has understanding, but has developed perspectives of science and technology that include the nature of science, the role of science and technology in personal life and society).

Shamos (1995)

- Cultural literacy refers to the factual information needed to read newspapers or magazines and involves rote recall rather than an understanding of scientific terms. It has the unfortunate connotation that adults operating at this level often assume they are literate in science.
- Functional literacy relates to some understanding of science ideas and adults at this level can engage in meaningful conversation about scientific issues, although the discussion tends to largely draw on recall with some understanding.
- True science literacy involves knowing about the theories of science. At this level, adults are aware of some major conceptual schemes that form the foundation of science, the role of experimentation in science, elements of investigation and the logical thought processes, plus the importance of a reliance on objective evidence.

PISA (OECD, 2003)

- “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”.

OECD/PISA (2007) moved into 3 areas

- Scientific concepts, which are needed to understand certain phenomena of the natural world and the changes made to it through human activity. The concepts are the familiar ones relating to physics, chemistry, biological sciences and earth and space sciences, they need to be applied to real-life scientific problems rather than just recalled. The main content of the assessment is selected from within three broad areas of application: science in life and health; science of the earth and the environment and science in technology.
OECD/PISA

**Scientific processes**, which are centred on the ability to acquire, interpret and act upon evidence
- the recognition of scientific questions
- the identification of evidence
- the drawing of conclusions
- the communication of these conclusions
- the demonstration of understanding of scientific concepts

OECD/PISA

- scientific situations, selected mainly from people's everyday lives rather than from the practice of science in a school classroom or laboratory, or the work of professional scientists.

As with mathematics, science figures in people's lives in contexts ranging from personal or private situations to wider public, sometimes global issues.

Meaning of STL

Developing the ability to utilise sound (accepted by the scientific community) science knowledge in everyday life to solve problems, make decision and hence improve the quality of life (resolve social values).

(Holbrook and Rannikmae, 1997)

The emphasis of STL is thus – developing abilities for problem solving, socio-scientific decision making (involving social values and argumentational – communicative – skills)

Meaning of Science Education

(Holbrook & Rannikmae, 2007)

**Now comes the problem.**

What is science education?
(or scientific education if you prefer)

Is it based on
- **Science** through education?  X
  *sometimes called “education in science”*
  or
- **Education** through science?  √
Goal of Education through Science

1. **Provide a foundation** – promoting a fundamental base of key science ideas, stressing key concepts, leading to complex science understanding/analysis/evaluation

   **OR**

2. **Education for life (citizenship or career)** – from identified concerns in society, promotes educational needs through scientific conceptual understanding (on a need-to-know basis), problem solving skills and socio-scientific decision making capabilities

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**A Foundation View of Education through Science**

- Leads to a comprehensive background, but one selected by scientists for a scientist’s world.
- Driven by content which gives scientific logic (in the eyes of scientists).
- Content can be conceptually expressed and represented by a concept map.
- Academic rigour (higher order cognitive learning) expected, but usually far from relevance (applicability) for life.

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**Education through Science based on relevance to society**

- Caters for the diversity of needs around the world (concerns and issues differ for different societies).
- Skills/values development given greater priority for problem solving and socio-scientific decision making, but still conceptual learning dominates.
- Program best represented by a consequence map (this is more diverse than a concept map).

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**The Science geared to Society Concerns (issues)**

- **This are likely to relate to**
  - Health, Food (agriculture), Environment, Energy, Technology/Industry, Resources, Information Technology and
  - Ethics and Social Responsibility
- **Source** - Sub-themes for an ICSU CTS Conference, Bangalore, India, 1985
**The Goals of Education**

- **Individual Development (Intellectual, Aptitudes, Attitudes)**
- **Social Development (Cooperative, Leadership Skill, Social Values)**

**Acquiring the Nature of Subjects**

**For Science Education**

**Categories of theories**
- Behaviorist Theories
- Cognitive Theories
- Constructivist Theories
- Descriptive Theories
- Design Theories & Models
- Humanist Theories
- Identity Theories
- Learning Theories & Models
- Motivation Theories
- Paradigms and Perspectives
- Social Learning Theories

**Theories behind**
Constructivist Theories

Communities of Practice
“groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly.”. Three components are required: (1) the domain- shared interest, (2) the community- shared activities, helping each other, (3) the practice – practitioners who share and develop.
Jean Lave & Etienne Wenger

Descriptive Theories

Activity theory- Vygotsky, Leont’ev, Luria
- Object-orientedness (people live in reality)
- Internalization/externalization. Internal activities cannot be understood if they are analyzed separately from external activities, because they transform into each other.
- Mediation. Human activity is mediated by tools in a broad sense. Tools are created and transformed during the development of the activity itself
- Development. Development is not only an object of study, it is also a general research methodology.

Motivation Theories

ARCS Model of Motivational Design (Keller)
- Attention (Active participation –Variability, Humor, Incongruity and Conflict, Specific examples, Inquiry)
- Relevance- To do this, use concrete language and examples with which the learners are familiar. -experience, present worth, future usefulness, needs matching, modelling, choice
- Confidence (success, feedback, learner control)
- Satisfaction

Design-Based Research Methods (DBR)

set of analytical techniques to bridge theory and practice in education Brown (1992), Collins (1992)
- The need to address theoretical questions about the nature of learning in context
- The need for approaches to the study of learning phenomena in the real world situations rather than the laboratory
- The need to go beyond narrow measures of learning.
- The need to derive research findings from formative evaluation
Contextual learning theory

Hull (1993) learning occurs only when students process new information or knowledge in such a way that it makes sense to them in their frame of reference (their own inner world of memory, experience, and response).

John Dewey, Kurt Lewin, David Kolb

Lewin's Equation

• B=f(P,E), is a psychological equation behavior is a function of the person and his or her environment

1944 action research

Experimental learning

David A. Kolb (Dewey, Piaget, Lewin)

4 type of learners:
- A converger (active experimentation-abstract conceptualization),
- B accommodator (active experimentation-concrete experience),
- C assimilator (reflective observation-abstract conceptualization), and
- D diverger (reflective observation-concrete experience).

STL Teaching materials
Research Objectives

- To follow and document the sustainability of science teachers' change towards STL teaching measured as ability to develop and use socially derived teaching materials establishing a student-centered classroom environment.
- To find categories that describe science teachers' permanent change towards STL teaching and factors influencing the process of professional development over 5 years period.

Findings

Teachers after 8 months intervention can be described by 3 categories:
- A Subject content teaching oriented (7)
- B Skills development oriented (6)
- C Oriented towards social issues (9)

Findings

- After 2 years, new categories were found:
  - D Motivational relevance (6) - using scenario type approach, still following the textbook
  - E Higher order skills relevance (5) - PS
  - F Social relevance (7) scenario linked with socio-scientific DM
Teachers’ change

Figure 1. Outcome space of categories reflecting teachers' satisfied change.