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MAKING CHEMISTRY TEACHING RELEVANT

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Introduction

Research has shown that chemistry teaching

- is unpopular and irrelevant in the eyes of students (Kracjik et al., 2001; Osborne and Collins, 2001: Pak, 1997; Sjoberg, 2001; WCS, 1999; ICASE, 2003).
- does not promote higher order cognitive skills (Anderson et al, 1992; Zoller, 1993).
- leads to gaps between students wishes and teachers teaching (Hofstein et al. 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, 2001a).

A factor common to all of the above seems to be the lack of relevance of chemistry teaching. Although school chemistry programs set out to develop conceptual understanding in students and an appreciation of the way scientists do things, the relevance of the teaching in providing a useful education is suspect (Pak, 1997; Yager, 1996; Champagne et al, 1985; Lederman, 1992; Novick and Nussbaum, 1981; Osborne and Freyberg, 1986; Ryan and Aikenhead, 1992). The stress on conceptual understanding and the appreciation of the nature of science tends not to be relevant for functionality in our lives i.e. relevant to the home, the environment, future employment and most definitely for future changes and developments within the society. Rather, the understanding tends to be geared to internal concepts within the subject itself. Concepts such as atomic structure, or chemical bonding are almost universally section headings in chemistry courses, yet in daily life, for example - improving the quality of the air for our health, is potentially a much more relevant starting point.

Generalising, chemistry curricula tend to put the subject first, and applications a poor second. Forgotten is that relevancy is in the processes and products we utilise in society, and only afterwards in the understanding (should we wish to utilise scientific principles in solving a problem or making a decision). Thus, in terms of relevant conceptual learning, it would seem that current curriculum approaches are not providing the impetus to promote the popularisation of chemistry that is expected. It would seem we need to find ways to initiate teaching based on societal situations and then develop the conceptual learning that allows students to appreciate the relevance of the science (Holbrook, 1994).

Relating chemistry to the developments in society is not new. Many so-called STS programs do this (Yager 1996, Lutz 1996). But while STS or context-based teaching programmes have included social values in the teaching, the relevance of the course is

still suspect. It seems that to achieve relevance there is a need to go beyond the simple inclusion of societal links. Attitudes towards the learning of chemistry are important and for this the need for interacting with issues in society by utilising the conceptual chemistry acquired is important but insufficient and there is a need to go further and incorporate the making of rational decisions geared to societal concerns. However, these are areas that are rarely considered in many chemistry courses (Rannikmae, 2001a).

To better understand the issue of relevance of chemistry teaching, it is suggested three aspects need to be considered:

- What are we trying to do ?
- How to guide teachers ?
- What could be relevant teaching materials ?

Or to express this in an alternative manner, the relevance of chemistry needs to embrace:

a) a relevant chemistry education philosophy;
b) a relevant curriculum;
c) relevant teaching approaches to the teaching of chemistry in schools;
d) relevant assessment and evaluation strategies;
e) relevant professional development for teachers.

The Meaning of Chemistry

As a first step to better appreciating the type of chemistry teaching needed, it is appropriate to establish the meaning of chemistry. Simply put, this has been suggested as

- a body of knowledge
- a way of thinking

Building on such a concept, the nature of chemistry needs to accept that chemistry knowledge is simultaneously reliable and tentative. And also the processes of chemistry utilise the so-called scientific method, which while not being one single entity, captures the chemists demand for naturalistic explanations supported by empirical evidence and involving observation, rational argument, inference, scepticism, creativity and the importance of being able to replicate work.

The Meaning of Education

Education, on the other hand, is to acquire the knowledge, skill and values, both personal and social, deemed appropriate for the society. In the past, education was sub-divided into cognitive, affective and psychomotor domains. Although the affective domain was clearly important, the role of the psychomotor domain was not well understood and education tended to stress the cognitive domain only. Today, education components are more likely to cover intellectual, communicative, social and moral, personal and physical, and aesthetic attitudes (Hong Kong Curriculum Development Institute, 1993). However, by noting that communicative and aesthetic qualities are linked to the individual, whereas social and moral are more societal aspects, it is suggested that the sub-division can be more conveniently expressed as Cognitive, Personal and Social domains. While the cognitive domain is still stressed, there is a clear recognition of the need to educate the individual and to develop social attributes towards creating responsible citizens.

The Meaning of Chemistry Education

But is chemistry education 'chemistry through education', or 'education through chemistry' ? It other words, does it need to be considered as a component of chemistry as a body of knowledge, or as a component of education ?

The following table gives a comparison illustrating the differences in emphases between 'chemistry through education' and 'education through chemistry'.

Chemistry through Education	**Education through Chemistry**
Learn fundamental chemistry knowledge, concepts, theories and laws.	Learn the chemistry knowledge and concepts important for understanding and appreciating socio-scientific issues within society.
Undertake the processes of chemistry through inquiry learning.	Undertake investigatory scientific problem solving to better understand the chemistry background related to socio-scientific issues within society.
Gain an appreciation of the nature of science.	Gain an appreciation of the nature of science.
Undertake practical work and appreciate the work of scientists.	Develop personal skills related to creativity, initiative, safe working, etc.
Develop positive attitudes towards chemistry and scientists.	Develop positive attitudes towards chemistry as a major component in the develop of society and scientific endeavours.
Acquire communicative skills related to oral, written and symbolic/tabular/ graphical formats.	Acquire communicative skills related to oral, written and symbolic/tabular/ graphical formats.
Undertake decision making in tackling scientific issues.	Undertake socio-scientific decision making related to issues arising from the society.
Apply the uses of chemistry to society and appreciate ethical issues faced by scientists.	Develop social values related to becoming a responsible citizen and undertaking chemistry-related careers.

Education through Chemistry

It is clear that the term 'education through chemistry' stresses education. And the medium through which this education takes place is the subject of chemistry. Chemistry education is thus no more about learning the ways of the chemist any more than history is taught to become historians, or language is taught to become linguists. Chemistry in school is part of the total education provision and the chemistry content is gained so as to enhance learning in the cognitive, personal and social domains.

It should be pointed out that nothing so far has been said which is contrary to the school curriculum. Nor is it contrary to the school chemistry curriculum. But nevertheless, it

seems to be a major change and seems to be rarely practiced. How do we get chemistry educators to recognise this?

A Shift of Emphasis

There is a need for a shift of emphasis tin the teaching of chemistry. The shift is from learning chemistry as a body of knowledge to promoting the educational skills to be acquired through the subject of chemistry. And as attempts to gain 'education through chemistry' simply by gaining knowledge are shown to be unsuccessful, the approach needs to shift from one bound by subject chapter headings, or sections to one which more closely relates to the issues and concern within society. Also, to ensure relevance of the conceptual learning within chemistry for social issues, there needs to be a shift from an introduction of the issue followed by the conceptual learning towards the interacting with the issue in a social context and then, as an important step, making use of the conceptual chemistry that is being learned to arrive at a socio-scientific decision.

The shift from conceptual learning within a subject context to conceptual learning in a social context, and which leads to socio-scientific decision making, can be illustrated by converting a concept map into a form more closely linked to the teaching and into a form which incorporates the socio-scientific decision making. This shift is promoted as a major attempt to move to more relevant chemistry teaching in the eyes of students.

The following attempts to illustrate the change for relevance using the Topic of Chlorine (in the following three pages).

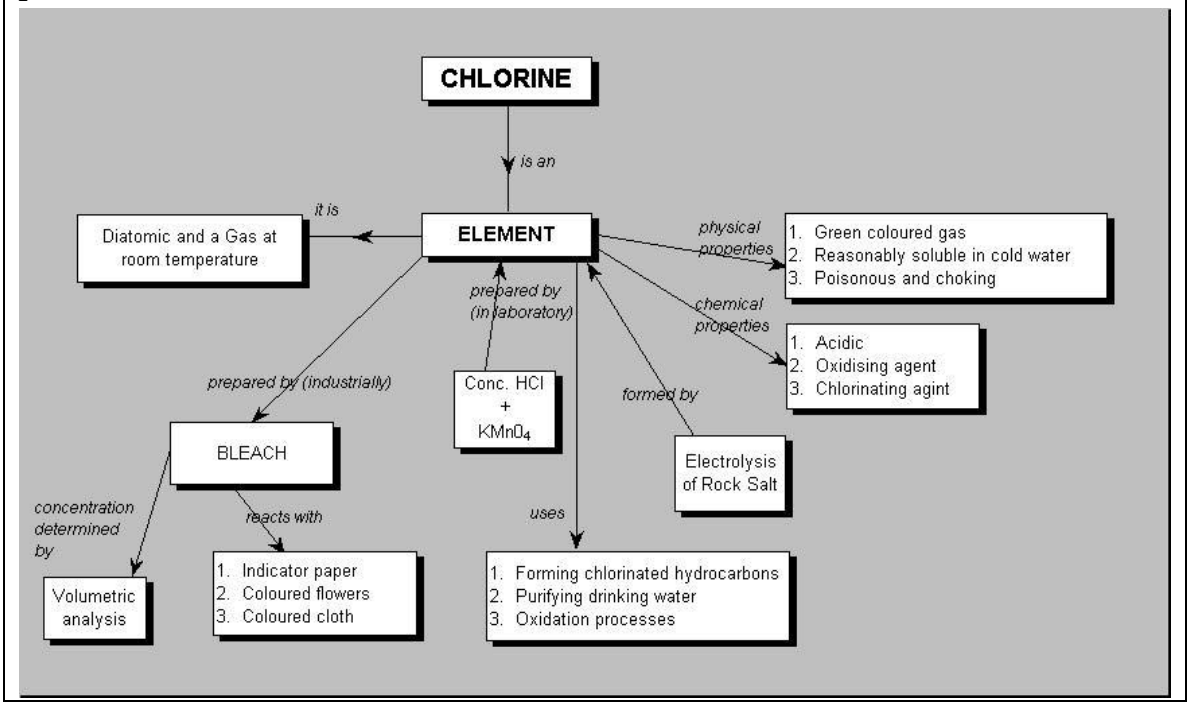
The Teaching Approach for Relevance follows the reformed map

Teaching geared to the goals of education covers a wide range of intended targets in the intellectual, personal and social domains. Conceptual learning within the subject needs to be approached in a relevant manner, but also the teaching must not lose sight of the fact that the attitudes, communication abilities and personal attributes (such as creativity, initiative, safe working) need to be developed. Strongly this suggests a societal beginning for the teaching approach. And by also encouraging student involvement, a teaching approach that builds on prior constructs held by students, thus enhancing relevance in the eyes of students.

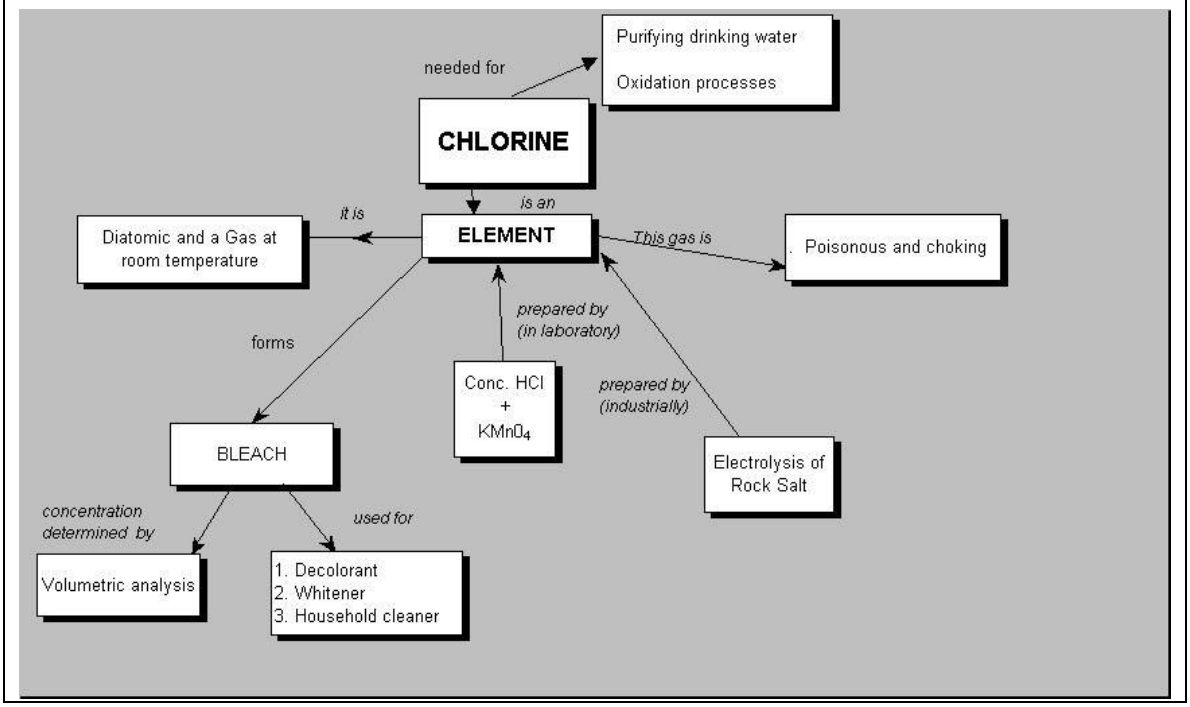
The suggestion is that the teaching of a sequence of chemistry lessons begins from a relevant socio-scientific context. The teaching progresses from the societal (the familiar), to the chemistry concepts (the unknown), which are needed to better appreciate the issues, or concerns, and then proceeds to the socio-scientific decision making needed (the purposeful learning involving all educational domains). Teachers need to recognise that curricula promoting chemistry fundamentals, grouping chemistry concepts for scientific convenience, rather than for popularity, is not the approach to promote education through chemistry. Such an approach leads to an academically perceived course that is likely to be abstract, difficult ad irrelevant.

A Possible Chlorine Concept Map

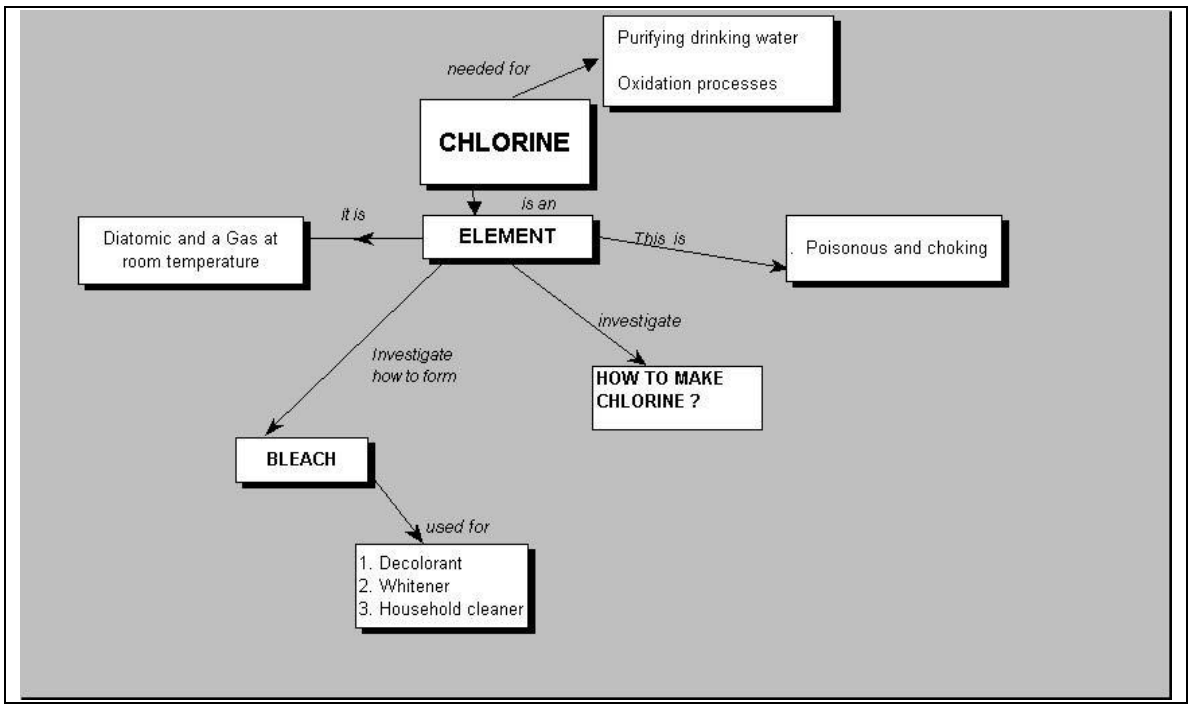
I



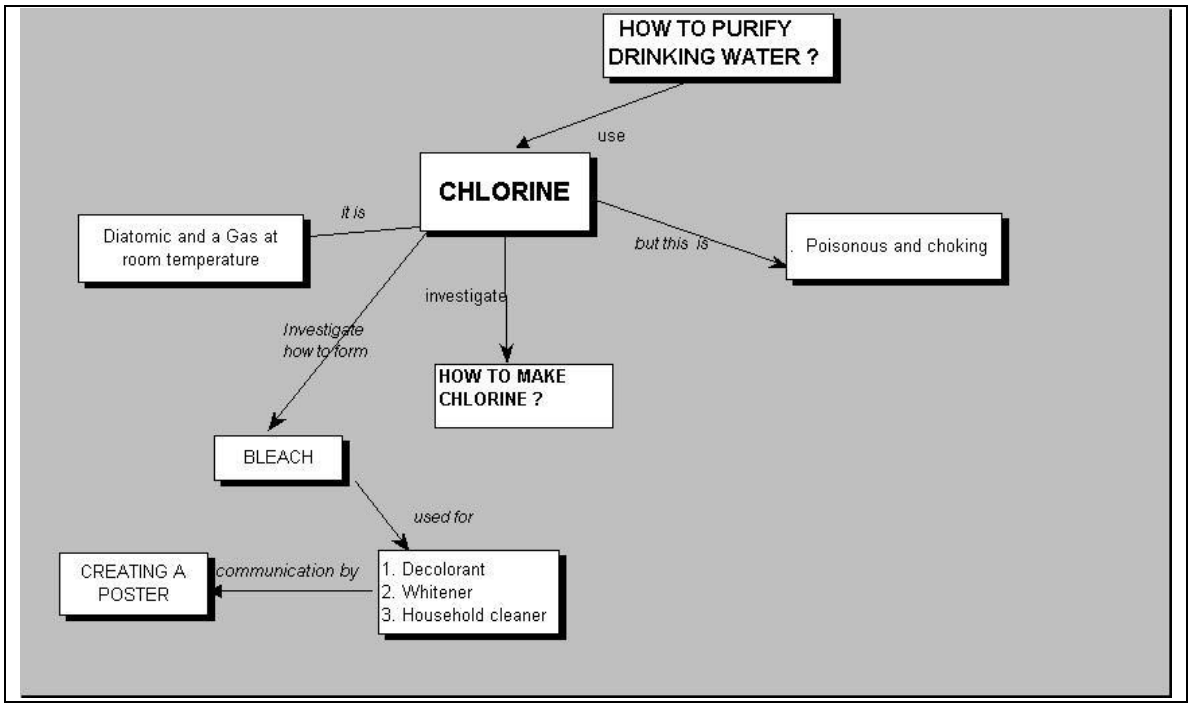
Transforming the approach and focus



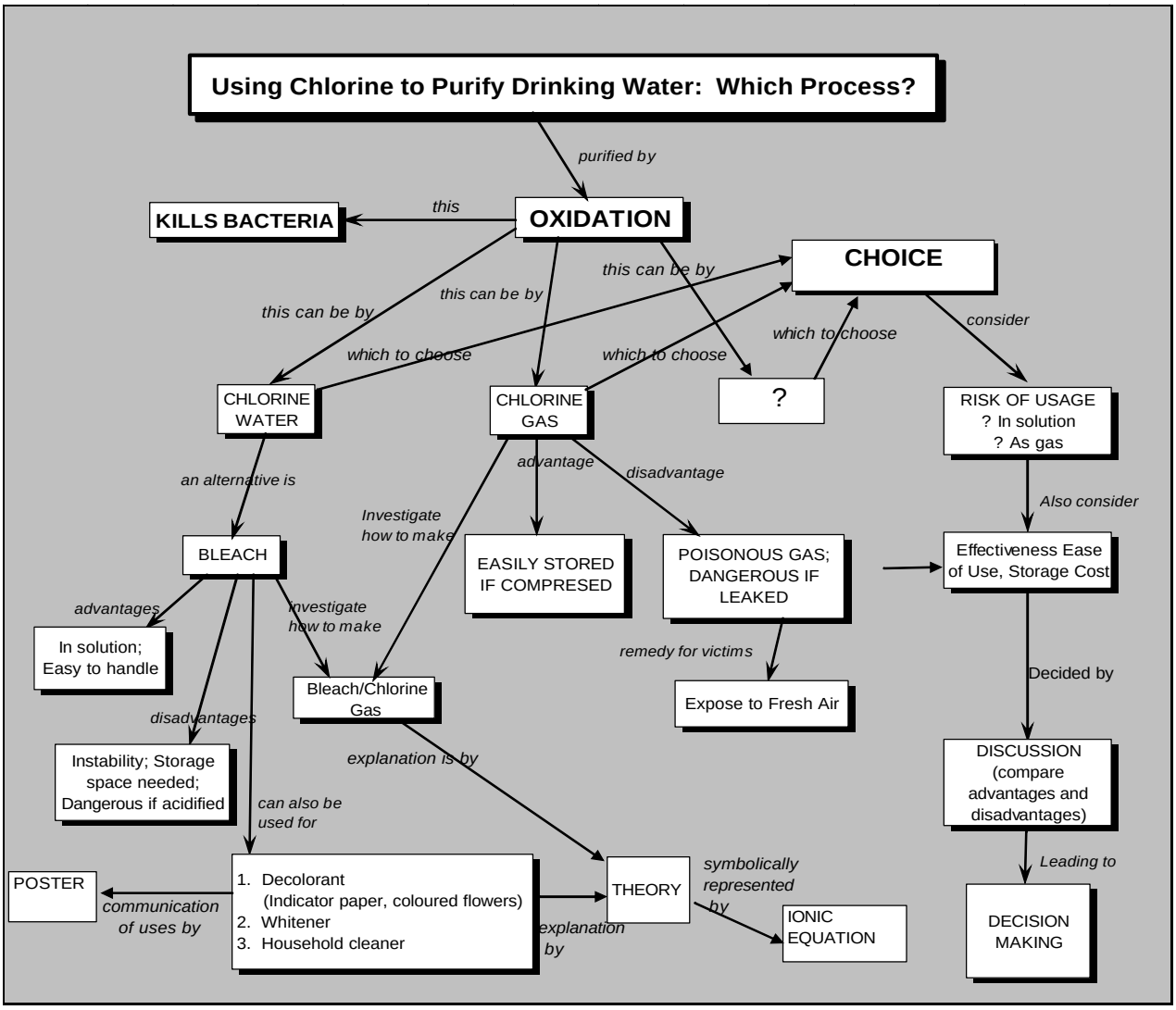
Adding Problem Solving Components (but still a focus on intellectual skills)



Introducing a Relevant Concern and adding creative communication



Adding socio-scientific decision making



The Suggested Way Forward for Chemistry Teaching

Much has been written about student centred teaching and teacher ownership of the teaching approach if the teaching is to be meaningful for students (Mamlok, 1998; Rannikmae, 2001b). With this in mind, it is suggested important that teachers are able to develop teaching materials which reflect the relevant teaching approaches being advocated.

As the teaching material is expected to relate to a societal situation, which students find relevant, it is suggested that the title of the teaching-learning material is likely to be a question. In this way, the title is related to an issue of concern for which a decision is required and for which the student first needs to gain chemistry conceptual ideas. The title tries to avoid the use of chemistry conceptual expressions, because these may be unfamiliar to the students, or not seen as relevant.

The title is followed by an introduction. Each teaching material needs an introduction. This is a very short outline of what the teaching material is about and guides the reader towards expectations they can have for utilising this material in their teaching.

Learning outcomes are specified at the beginning of the materials so as to clearly specify the learning in terms of:

a. the intentions for learning based on the three educational domains, and
b. whether the learning has been achieved.

The emphasis is thus on the outcomes of learning, rather than the process by which they are achieved, although student participation in the process is considered crucial for motivation and hence interest.

Where the science conceptual outcomes are clearly specified in the exemplar materials, it is essential that they relate to the issue or concern that drew attention to the relevance of this learning. Active learning is promoted by learning outcomes related to chemistry process skills, whereas stress on the conceptual learning will mean additional outcomes in the science conceptual area.

The social values learning outcomes form the focus of the learning for all, except for younger students (primary level), and are usually expressed in a socio-scientific decision-making format. Such decisions need justification and will draw on the science conceptual learning, as well as other societal factors, such as environmental issues, economic issues, social factors, political factors to explain the decisions made.

The main component for the students is the student script. Within this a scenario sets the scene for activities to then be undertaken by the students. The scenario is related to the society, points to an issue or concern on which the script draws and thus builds on the title of the material. Usually the more personal the scenario, the more the student can identify with the situation and hence find it more relevant.

Besides the scenario, individual or group activities are given which are designed to enable students to achieve the learning outcomes. These are geared heavily towards

cooperative learning, promoting communication skills and either making societal decisions or solving societal problems. As it is important all lessons are under the control of the teacher, the strategy for introducing the students' scripts , the manner in which they are used and the way the lesson is conducted, is for the teacher to determine.

Two important skills are addressed in teaching for relevance – scientific problem-solving and socio-scientific decision-making. The first is practiced by involving students in investigatory activities in which the ultimate goal (acquired by practice over a number of occasions) is to be able to identify the scientific question, plan the investigation, predict the likely outcomes, identify and control variables, undertake the observations or recording of measurements made, decide on the number of a variety of observations/measurements, determine how to record the data, interpretation of the findings, presentation of the finding in a suitable format and conclusions of the investigation.

The second important skill is being able to make a justifiable decision (which is the ultimate purpose of the teaching material), but based, of course, on the scientific conceptual learning gained through the teaching material plus other social factors that may impact on the decision. The decision is not static i.e. the actual decision make could change with time, location and the attitude of the persons making the decision. A further goal therefore is to try to arrive at a consensus decision to show that it is a societal, rather than an individual decision that is important.

From the teacher's point of view, a teacher's guide is considered as the main part of the script. This gives guidance on how to use the script, in the manner intended. It assists the teacher by putting forward a teaching strategy, detailing how the intended educational learning outcomes are to be achieved, suggests assessment approaches and includes any additional handouts for the students that the teacher may wish to give later in the lesson.

A section on 'achieving the learning outcomes' is very important. It links the student activities to the learning outcomes intended. A section on 'assessment' is very much related to the achievement of the learning outcomes. It outlines the manner in which feedback from the students can be obtained (in a formative and/or summative manner) and hence help the teacher determine whether the activities have enabled the students to actually achieve the learning outcomes put forward.

Clearly, a marking scheme for formative assessment must be simple, if it is to operate in the classroom, in the manner described. It needs to be possible for teachers to award the mark through a variety of feedback mechanisms, depending on the situation.

Among the methods suggested are:

- observation of the students (by watching student activities, by watching students reacting to teacher comments, by listening to their comments in group work, whole class sessions),

interacting with students orally (teacher initiated by asking questions of different types – informational, procedural, reasoning, predictive, etc, student initiated by asking questions, by viewing/reading student's work),
making use of student-student assessment (students cross mark test/quizzes)

An example of how formative assessment can be carried out, using a 3-point system, is given below :

Teacher listens to the discussions and determines (for a student) whether socio-scientific decisions are meaningful (related to choosing a brand of shampoo and advertising) and then awards a "mark" as follows:

x Has not made a meaningful contribution to the decision-making discussions. Does not decide other than on economic grounds i.e. cheapest.

√ Participates in the discussion and recognises that a choice can be made on scientific as well as economic grounds. Considers other factors e.g. environmental or social, only when given guidance by the teacher.

√√ Plays a significant role in the discussions and reflect on many viewpoints from which a discussion could be made. Selects an appropriate choice based on social as well as environmental, economic and scientific grounds. Appreciates disparity that may occur between the best choice and actual practice within society.

In this 3 point example, the student can be awarded an" x, √, or a √√." Clearly "x" indicates the learning outcome, is not achieved and more learning is required. The "√" indicates the learning outcome is achieved and the student has attained the level of learning required for this component. The "√√" "score" is reserved for students achieving beyond the level intended and can be considered an important target for the more able students. By accumulating learning outcome "scores", a meaningful guide to the student's ability in this area is obtained.

With the science related to the world of relevance of the student, the science is unlikely to be fully covered in the standard textbook. An additional component of the material is thus background information for the teacher.

Further support for the teacher is given through suggested student handouts. These are materials that have been purposely included in the notes for the teacher so that the teacher has the choice of whether they are to be used or not. They are designed to be copied, or photocopied and given to the students when the teacher feels this is appropriate. The teacher also decides when it is appropriate to give the handouts to the students.

Promising Teaching Materials

Teacher workshops have been developed by ICASE (Holbrook and Rannikmae, 1997) in which teachers create supplementary teaching materials meeting the criteria, although it needs to be stressed that the major workshop goal is to give teacher ownership of the need for greater relevance through developing skills in creating suitable teaching material.

References

Aikenhead, G.S. (1997). Changes Need to Succeed Where We Previously Failed. In KEDI: Globalization of Science Education - moving toward Worldwide Science Education Standards. *Proceedings of the International Conference on Science Education*, May 26-30, 1997, Korea.

Anderson, R.D., Anderson, B.L., Varanka-Martin, M.A., Romagnano, L., Bielenberg, J., Flory, M., Miera, B. and Whitworth J. 1992. *Issues of Curriculum Reform in Science, Mathematics and Higher Order Thinking Across the Disciplines*. The Curriculum Reform Project, University of Colorado, USA.

Bell, B. (1998). Teacher Development in Science Education. International Handbook for Science Education. Part Two. Kluver Academic Publishers. p 681-693.

Champagne, A.B., Klopfer, L.E. and Gunstone, E.F. 1985. Instructional Consequences of Students' Knowledge about Physical Phenomena. In A.L. and L.H.T.West (eds). *Cognitive Structure and Conceptual Change*. New York, NY: Academic Press.

Curriculum Development Institute. 1993. *Guide to the Secondary/Sixth Form Curriculum*. Education Department, Hong Kong.

Hofstein, A. Carmini, M. Mamlok, R.. & Ben-Zvi, R. (2000). Developing Leadership Amongst High School Science teachers in Israel. NARST 2000: New Orleans. Conference Paper, 33p.

Holbrook, Jack. 1999. Assessing student achievement for Scientific and Technological Literacy (STL). *Science Education International*, Vol.10, No. 4, December.

Holbrook, Jack. 1998. Operationalising Scientific and Technological Literacy – a new approach to science teaching. *Science Education International*, Vol. 9, No 2, June.

Holbrook, Jack. 1996. The Role of Science Teacher Associations in Promoting Scientific and Technological Literacy. *Science Education International.* Vol. 7, No.1, March 1996, pp 5-10.

Holbrook, Jack. 1994. Scientific and Technological Literacy for All - The Role of Educators. *Science Education International*, Vol. 5, No. 3, September 1994, pp10-16.

Holbrook, Jack and Rannikmae, Miia (1999). Promoting scientific and technological literacy through the use of supplementary teaching materials. In K. Papp, Z.Varga, I.Csiszar, P. Sik (eds.) *Proceedings of the International Conference on Science Education for the 21st Century*. Szeged, Hungary; June 22-25.

Holbrook, Jack and Rannikmae, Miia (eds). (1997). *Supplementary Teaching Materials - Promoting Scientific and Technological Literacy*. Tartu, Estonia: ICASE.

ICASE. 2003. The Way Forward: A framework for action document. ICASE2003, "Increasing the relevance of Science and Technology Education for All in the 21st Century, Malaysia.

Krajcik, J: Mamlok, R; Hug, B. (2001). Modern Content and the Enterprise of Science: Science Education for the Twentieth Century. In: Corno, L. (ed). Education Across A Century: The Centennial Volume. One Hundredth Yearbook of the National Society for the Study of Education, 205-237.

Lederman, N.G. 1992. Students' and Teachers' Conceptions of the Nature of Science: A Review of the Research. *Journal of Research in Science Teaching*, Vol. 29, No.4, pp331-259.

Lutz, Martha. 1996. The Congruency of the STS Approach and Constructivism. In Robert E.Yager (ed). *Science/Technology/Society as Reform in Science Education*. Albany, New York: SUNY Press.

Mamlok, R. 1998. The effect of a teaching unit "Science as an ever developing entity" on students' perception and attitudes towards science learning, Unpublished PhD thesis, Weizmann Institute of Science, Israel

Novick, S. and Nussbaum, J. (1981). Pupils' Understanding of the Particulate Nature of Matter: A Cross-Age Study. *Science Education*, Vol. 65, No.2, pp 187-196.

Osborne, J. and Collins, S. (2001). Pupil's views of the role and value of the science curriculum: a focus-group study. International Journal of Science Education, 23(5), 441-467.

Osborne, R. and Freyberg, P. (1986). *Learning in Science: The Implications of Children's Science*. London: Heinemann.

Pak, Sung-Jae. (1997). A Challenging Conception of Science Teaching. In KEDI: Globalization of Science Education - moving toward Worldwide Science Education Standards. *Proceedings of the International Conference on Science Education*, May 26-30, 1997, Korea.

Rannikmae,M. 2001a. *Operationalisation of Scientific and Technological Literacy in the Teaching of Science.* PhD thesis. University of Tartu, Estonia.

Rannikmae, M. 2001b. Guiding teacher development towards STL teaching: identifying factors affecting change. Science Education International, 12(3), 21-27.

Ratcliffe, M. 1997. Pupil decision-making about socio-scientific issues within the science curriculum. *International Journal of Science Education*, 19, 167-182.

Ryan, A.G. and Aikenhead, G.S. (1992). Students' Perception About the Epistemology of Science. *Science Education*, Vol. 76, No. 67, pp. 559-580.

Sjoberg, S. (2001). ROSE: The relevance of science education. A comparative and cooperative international study of the contents and contexts of science education. [Online] http://folk.uio.no/sveinsj/ROSE_files.htm

WCS. 1999. Science Agenda – Framework for Action, point 41. World Conference on Science, Budapest. UNESCO and ICSU.

Yager, Robert E. 1996. Meaning of STS for Science Teachers. In R.E.Yager (ed). *Science/ Technology/ Society as Reform in Science Education*. Albany, New York: SUNY Press.

Yager, E. R. & Weld, J.D. (2000). Scope, Sequence and Coordination: The Iowa project , an notional reform effort in the USA. International Journal of Science Education, Vol. 21, N.2 p.169-194.

Zoller, U. (1993). Are lecture and learning compatible ? Maybe for LOCS: unlikely for HOCS. Journal of Chemical Education, 70, 195-197.