Public Awareness Of Science

How Can Recent Research Influence Primary Classroom Practice?

Dr. Susan M. Stocklmayer
The Australian National University
Canberra, Australia
(Sue.Stocklmayer@anu.edu.au)

Abstract

Why do we teach science? The public understanding and awareness of science, and their relation to formal education, are attracting increasing attention internationally as the general public becomes more aware of important and contentious scientific developments such as genetically modified organisms. In this paper, world trends in public awareness initiatives are examined, especially their significance for primary science education. The "big picture" of science education is the central topic - is our education appropriate, how should we change what we currently do, where are we all going? How can the Asia-Pacific region better adapt its science education to its needs and its peoples? The problems of research into public understanding and scientific literacy are described, together with some outcomes from recent investigations in Australia and elsewhere.

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The communication of science to primary students lays a foundation for lifelong attitudes and aspirations. Primary school is the point at which seeds can be sown, for nurturing throughout high school and beyond, or the point at which problems can be created which never go away. It is relevant, therefore, to look at what is happening in progress toward public awareness, or, as it has usually been called, public understanding, for we now have a fair idea of the likely results in adulthood of primary experiences in science.

For some time now, the public understanding of science – or, if you prefer, scientific literacy – has been a declared goal of many nations. According to the Royal Society of London, a scientifically educated public is desirable because that situation benefits: national prosperity (for example, by giving a better trained workforce); economic performance (for example, by having beneficial effects on innovation); public policy (for example, by leading to better informed public decisions); personal decisions (for example, over the use of tobacco, choice of diet, by an individual); everyday life (for example, understanding what goes on around us); the understanding of risk and uncertainty (for example, in relation to nuclear power generation and waste disposal); contemporary thought and culture (for example, science is perceived as a rich area of human inquiry and discovery) (see: Irwin and Wynne 1996, p.5).

A commonly held view in many countries is that greater public education entails better understandings by the public of the key concepts that science has produced, of the methods of enquiry used in science, and of the social processes by means of which science takes place (Millar 1996).

These are clearly laudable goals. Nevertheless, the public understanding movement, which began in Europe in the 1960s, has not achieved these goals, and is very far from their realisation. Why?

Let us take a brief look at some recent public statements made by policy makers in Europe, the United States, and elsewhere. Why should we, here in Asia, focus on Europe and the United States? It is because the trends we see in world science education tend to start there, with the rest of us adopting those ideas in the fullness of time. This, it seems, is the way we all do it – and I shall return to this point later in this paper.

First to the USA, where the National Science Foundation has been very active in pursuing the goals of "science for all Americans" first articulated by President Clinton in 1993. The practical outcomes have been that large funds have been given to science education. Yet the situation in the USA is still critical and educators continue to analyse, to criticise and to look for ways to be creative in their efforts to improve classroom teaching. The quality of primary science in the USA is highly variable, often very problematic.

Now to Europe. In 1999, the UNESCO World Conference on Science in Budapest ended with a Declaration that science should be pursued for knowledge and development, for progress and for peace. The Framework for Action which resulted from that conference stressed science education and science communication as vital tools in pursuing these ends. Despite this, and subsequent key meetings in London, almost nothing has happened on the UNESCO front since 1999. There has been plenty of rhetoric but no action. In Europe generally, however, the past year or two has seen a flurry of activity, particularly with respect to public involvement in debate about issues such as genetically modified foods.

In England, matters were brought to public attention with the publication of two Government reports. In February 2000, the British House of Lords published the findings of a Select Committee on Science and Society. The report begins by stating that 'society's relationship with science is in a critical phase', citing recent developments in biotechnology and the BSE (mad cow disease) disaster as eroding public confidence and creating public unease. The Select Committee found that there was wide mistrust of scientists, especially Government ones, and that this was 'breeding a climate of deep anxiety among scientists themselves' (p.1). This report was deeply critical of the public understanding movement, dubbed "PUS" which, it said, implied a top-down, arrogant view of the public. "PUS" has been widely criticised, in that it implies that people need educating so as to reach some undefined standard which, when attained, confers "understanding". Wynne (1993) has termed this the "deficit model" because it inevitably constructs a public that is lacking in knowledge.

The second report, commissioned by the House of Commons, investigated the goals and the present state of science education. In summary, this report found that science education was irrelevant, boring and unnecessarily difficult.

Where, then, are we going wrong? What should be the goals of science education, particularly at primary level? Sjøberg (2002, p.4) raises a series of questions about science and technology education. He asks whether we should favour early specialisation, identification and recruitment of the more able, or have a comprehensive system for all. Should one maximise students' individual freedom to choose? How should one support life-long education and develop adult education and on-the-job training? These questions relate to what should be taught, to whom, and when. Sjøberg concludes by saying: "One will need to look beyond the education system and involve different stakeholders. There is a need for context specific reforms with a multi-dimensional approach and long-term implementation (p. 5)."

We believe that, for the adult members of the public (who are, after all, the final product of primary education) the issue comes down to one of ownership. This ownership is impeded by problems of access. There is little doubt that, when the occasion demands, ordinary 'unscientific' people *can* become very expert, very knowledgeable, very much in command of the science. With respect to public understanding, there have been many authors who have examined in detail case studies of public crises in which those concerned became 'experts' on the issue at hand. In their book *Misunderstanding Science? The public reconstruction of science and technology*, Irwin and Wynne (1996) recount a number of instances in which this has occurred. For example, the hill sheep-farmers in the Lake District, when faced with radioactive contamination following Chernobyl, 'entered the scientific arena... redrew its boundaries, and, operating with different presuppositions and inference rules, also redrew its logical structures' (p.31). For the ordinary person, however, becoming an expert is extraordinarily difficult. Accessing scientific knowledge is too hard, people's background in science does not equip them for the task, and the language of science presents a barrier that is very hard to surmount. In other words, their school science is of no help to them. They have the facts – the content – but no skills to interpret and transfer this knowledge.

The problem, we believe, in using content knowledge as the criterion of public literacy-and, by extension, the focus of science teaching - is that it, by definition, produces the 'deficit model' described by Wynne (1993). The Select Committee of the House of Lords shares this concern. A recurring theme in the Report is questioning the value of the phrase 'public understanding', which the Report interprets to mean 'the understanding of scientific matters by non-experts'. Bryant (1998) has defined it in more detail:

> The public understanding of science is the comprehension of scientific facts, ideas and policies, combined with a knowledge of the impact such facts, ideas and policies have on the personal, social and economic well-being of the community.

I am sure you would agree that these are, in the main, the explicit or implicit goals of most science syllabuses worldwide. Are they the right ones?

The connotations of knowledge and comprehension of facts have been explicitly stated by the Select Committee as problematic:

> It is argued that the words imply a condescending assumption that any difficulties in the relationship between science and society are due entirely to ignorance and misunderstanding on the part of the public; and that, with enough public-understanding activity, the public can be brought to greater knowledge, whereupon all will be well. This approach[27] is felt by many of our witnesses to be inadequate; the British Council went so far as to call it 'outmoded and potentially disastrous' (p 140).

Let us consider the implications of this public understanding idea. It implies that there is, "out there", a set of understandings which we should all have. What are they? How do they relate to what we teach? There has been a number of surveys, dating from the 1980s, which have set out to discover the answer. These surveys (e.g. Durant, Evans and Thomas, 1989) have quizzed the public on their knowledge of a range of facts drawn from universally taught topics at a fairly elementary level. The tests have shown that many of the public do not know that the earth goes round the sun, that common salt is sodium chloride, that antibiotics will not kill viruses. Is this knowledge important? Is there some body of knowledge we all should share? Who decides what it should be? Is it your school syllabus, or mine?

Over the past few years, Australia's National Centre for Public Awareness of Science has been conducting workshops for practising scientists of all disciplines and from many different countries of origin including the UK, USA, Australia, New Zealand and many countries of Asia. The subject of these workshops is effective communication with the public. The workshop facilitators have found that it is a common view amongst scientists, particularly older ones, that responsibility rests with the public to learn more science. Indeed, one scientist expressed the view that it was the *duty* of the public to learn more science, given the benefits they obtained from it. A small part of these workshops has therefore involved a consideration of the issues of understanding, literacy and awareness.

Part of a very well-established survey (Durant, Evans and Thomas, 1989) has been used to provoke discussion.

The scientists are given a section of the questionnaire and asked to complete it before making comments. To date almost 200 scientists have taken part, from disciplines including physics, chemistry, environmental, agricultural and medical sciences. Although this research is still in progress, preliminary results indicate that, on many knowledge-based questions, the scientists are unsure of their answers or are deeply critical of the questions. Not one of the scientists felt completely confident of their answers to every question and many admitted frankly to ignorance of several questions outside their discipline. There was no question on which all the scientists were correct (Rennie and Stocklmayer, 2003).

Significantly, these findings indicate that, when outside their own discipline, scientists often are just as ignorant as the general (presumably lay) public. Given this, we might ask: Does lack of scientific knowledge really matter? The scientists themselves are deeply divided on this issue. Some are "shocked" at the public's ignorance but many recognise, in their own inability to be certain of their answers, that the public cannot be expected to retain facts that are not useful.

It should not come as a surprise that these scientists did not know all the answers. When you consider the normal pattern of a scientist's education, progress to about age 15 will have the same broad base as you or I. After this, they may specialise in certain scientific disciplines in upper high school. Let us say that biology is the chosen field. Physics, then, takes a back seat except in the limited overlap between the disciplines. Progression through undergraduate and postgraduate degrees further marginalises physics until, at the end of the training of these scientists, they are expert in an ever-narrowing field of biology. On the other hand, their physics education is highly limited and their general science knowledge no wider than yours or mine.

Are they, then, lacking in scientific literacy? I suggest that they are not – that their lack of knowledge of physics is not important. What they have is a very great degree of comfort with science, its processes and its ideas, its methods and its history. They are literate in the best possible way – a way that facilitates further exploration, a broad "feel" for science and an understanding of how to find and use scientific information.

The community's relationship with science has become increasingly important, as new science-based technologies require more public comment and involvement. In Australia, a Working Group report to the Prime Minister's Science, Engineering and Innovation Council, pointed out that "it is vitally important that the community is able to relate science to everyday life and in this way appreciate how science improves our economic, social and cultural well-being (p. 1)." In Australia this is frequently linked to "more effective" or "better" science education. Is it really this simple?

As explained in Rennie and Stocklmayer (2003), qualitative findings from several case studies suggest that public understanding is actually a highly sophisticated matter. These more detailed studies reveal the extent to which people individually restructure and recontextualise scientific information into a knowledge which is useful for them (Layton, Jenkins, Macgill, & Davey, 1993; Turney, 1996). They support Wynne's (1993) criticism that the major research techniques in the public understanding of science have been developed without identifying and examining the assumptions upon which people build their knowledge. In reality, for most people, scientific facts tend to take a back seat.

Two issues are significant for adults (Rennie and Stocklmayer, 2003). First, it is essential that we recognise the *individualness of people's thinking* about and dealing with scientific knowledge, and second, *people can choose* whether or not to engage with and think about science. The first issue applies to everyone, adult or child. The second, regrettably, is not true for students because they have to engage with science if they are to pass the required examinations. They do not have a choice. Research has shown, however, that for many this engagement and knowledge lasts for a very short time once they leave school.

Clearly, increasing scientific literacy is more than just bringing science and technology to people's attention or teaching them more science content, it requires increasing awareness of what science and technology are about and willingness to engage with them. When adults do engage with science, a good deal of mental work is usually involved before it becomes useable by them. As Jenkins (1994) points out, "most lay people find conventional scientific knowledge of little or no use as a basis for action in their social context unless it is reworked, restructured and recontextualised (p. 603)."

Are these findings about adults related to primary experiences? I believe that they are directly and fundamentally connected. If we are to teach science effectively at any level, we need to recognise that what we are developing is *not* a wide knowledge of facts – for these are soon forgotten. It is *not* the ability to conduct experiments to confirm long-held knowledge, for this is not creative. It is to develop what we term the *personal awareness of science and technology*. In this way, the reworking and recontextualising of knowledge referred to by Jenkins (1994) will be facilitated.

The personal awareness of science and technology has been defined by Gilbert and Stocklmayer (2001, p. 43) as "a set of attitudes, a predisposition towards science and technology, which are based on beliefs and feelings and which are manifest in a series of skills and behavioural intentions." This definition provides for long-term personal development, in school and beyond. Gilbert and Stocklmayer argue that development of personal scientific attributes depends upon the level of skills of accessing scientific and technological knowledge and the degree to which a sense of ownership of that knowledge is held by that person. In the longer term, and dependent upon subsequent experiences, the person can develop "an understanding of key ideas/products and how they came about, to an evaluation of the status of scientific and technological knowledge and its significance for personal, social, and economic life."

Thus the definition allows development through many levels of understanding and makes no attempt to define what these levels, in terms of scientific knowledge, might be. It carries with it an expectation that awareness will be enhanced through ownership and access, through personal experience and exploration, rather than by didactic transmission-style teaching of the traditional kind. It implies that no 'progress' can be made except through personal meaning-making, a view which is consistent with major versions of constructivist learning theory. It provides for multicultural approaches to science education.

This definition also provides for measuring change in how people think about science along a continuum of attitudes and skills, rather than a one-dimensional, content-based, 'right or wrong' assessment. It has led to the Model for Personal Awareness of Science and Technology described in Stocklmayer and Gilbert (2002). The application of this model may extend to any interaction which people have with the worlds of science and technology and their many communication modes.

This model proposes an iterative process of learning. Applying it directly to primary experiences, let us consider that a lesson, or sequence of lessons, is designed to teach a "target" area of science. (Figure 1). A student interacts during these lessons – but the student does not interact directly with the target science. Rather, the student interacts with the *experiences* the teacher has provided. They may be textbook based, they may be hands-on experimentation, they may be shown in video or on the world wide web. Whatever the experience, constructivism states that the student brings to bear what they already know. We have termed this their *Personal Awareness of Science and Technology* at this time (PAST1).

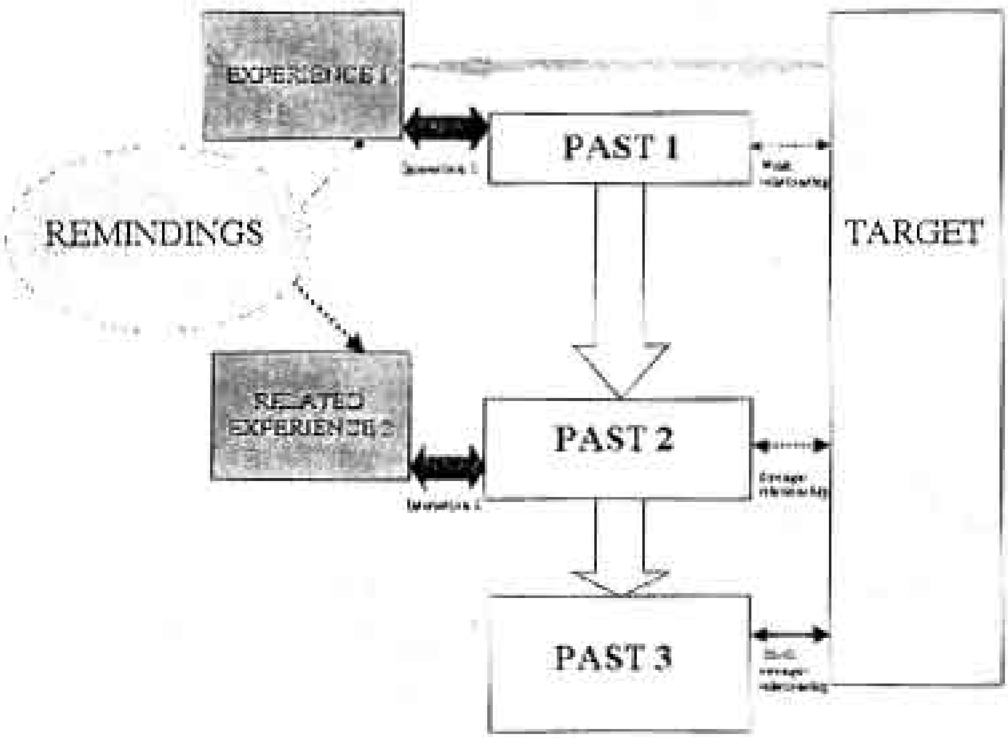

Figure 1. A Model for the Personal Awareness of Science and Technology (Stocklmayer and Gilbert, 2002).

The student understands the interaction in terms of personal meaning-making, which is enhanced by the quality of the *remindings* (Barsalou,) that the experience evokes. If the remindings – the mental links to the world of the student – are strong, then the interaction will have meaning and links to the target may be made. The result is a new level of awareness, PAST 2. The connection with the desired target may, however, be quite tenuous at the time of the interaction. A further experience related to the same target will be informed by a new, stronger set of remindings which will, in their turn, increase the connection to the target. This iterative process can occur indefinitely.

The model places all the emphasis upon the *experiences* - that is, the quality of the lessons - since they are the way in which the student encounters the underlying science. Good design of such experiences is critical – and good design implies facilitating interaction and understanding (Stocklmayer and Gilbert, 2002). The challenge for teachers is to provide those contextual experiences, to provide for the link with the 'target' to be clearly delineated and to encourage further interaction. It is not a simple process and *engagement* is the key to its success.

How might this process go wrong? First, it could be that the lesson is too abstract, too remote from personal experience. Usually, this means that the lesson is not tailored to the students but is too close to the target (Figure 2). In this case, the student cannot make the connections. Remindings are few, and weak, and engagement is limited. The student may rote-learn what is on offer, but will not understand. It will be quickly forgotten.

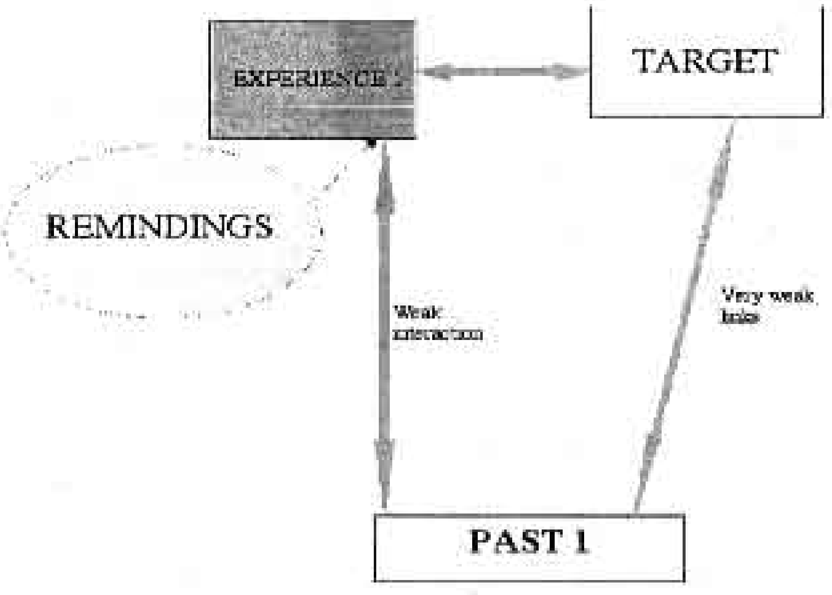

Figure 2. Problems when the experience (the activity or the presentation of the concept) is not contextually relevant.

Second, it could be that the lesson is very close to the world of the student – an activity such as baking cakes, which is a popular one in Australian primary science. In this case, remindings will be strong and engagement will be high – but the target science may be very obscure. The target in this case may be so far from the observable lesson that the students miss it altogether.

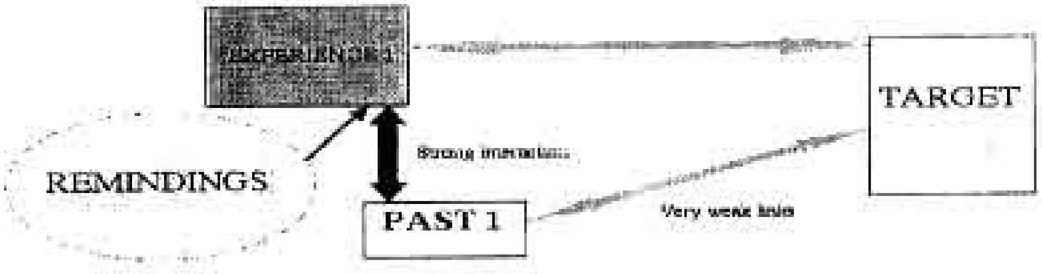

Figure 3. Problems when the experience (the activity) is analogically remote from the target (the science underlying the activity).

Implicit in the model is iteration – the so-called spiral curriculum, to which we often aspire but seldom achieve. For life-long learning, these iterative connections are essential to build a conceptual framework which is so firmly linked to the world of the learner that *transferability* becomes possible. Facts and theories on their own are not enough.

We have said elsewhere that there should be a review of the notion of there being scientific facts that are reasonable for people to know (Rennie and Stocklmayer, 2002). What is needed is urgent debate and reform. Should we concentrate on science as process, science as history, science as uncertainty? One of the problems of primary teaching of science is the so-called lack of science training of primary teachers. They are, increasingly, being asked to load their syllabus with scientific ideas, concepts, and facts. We have conducted workshops with teachers in many countries and we know that they feel very pressured by these demands. This pressure is felt also by secondary teachers, as the ever-increasing knowledge base of science is pushed downwards into the school system.

It must stop, because it is not achieving the desired outcomes. If science education is indeed irrelevant, difficult and boring, it must change. It must become relevant, easier to access, and interesting. It is in one sense simple to do this – we must tailor it to what we know is going to be useful in the world beyond school and we must begin that spiral learning in primary school. It must be gentle, enjoyable, and creative, not filled with facts and abstract ideas, but tapping into the cultural world of the learner.

Science at present does not take much account of cultural differences. It is as though we are teaching it in a cultural vacuum. We do not, most often, recognise that Western science has its own culture, its own ways of doing things which are often alien to our students and which set up conceptual conflict in the outside world beyond the classroom. Especially, we often regard science educational ideas originating in Europe and the USA as models of progress. This, too, must change.

None of this is new. It has been said many times by more knowledgeable educators than I. Yet we do not seem to hear. Those responsible for curricular reform impose ever-increasing demands on primary teachers to lay complex and abstract foundations in areas such as electromagnetism and atomic structure. This is unfair and unnecessary. It has been shown, over and over, to be counterproductive. It is frequently of little use to our own people in their ordinary lives.

I have written elsewhere (Rennie and Stocklmayer, 2003) that a vision for science education can be summarised as striving for, amongst other aims: people who feel that science and technology lie within their interest and their personal lives; people who are able to access new knowledge in science and technology and understand how it will affect their lives; people who feel comfortable about processing relevant scientific information. These aims will not be achieved by primary syllabuses which are overcrowded and stressful for teachers. A strong stance needs to be taken by primary decision-makers. We must be firm, not least with those at secondary level who dictate overall policy. We *know*, from research and from experience, what works with students in terms of effective learning. We should heed the teachers who tell us that the system inhibits this learning, and we should redesign the syllabus for a positive, interested body of students who will carry our desires for an innovative, creative, scientifically confident society into the future.

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[1] "Raising Awareness of the Importance of Science and Technology to Australia's Future" Agenda item 3, Fourth Meeting, 26 November, 1999, Prime Minister's Science, Engineering and Innovation Council.

Title : **Public Awareness Of Science: How Can Recent Research Influence Primary Classroom Practice?**

Presenter : Prof. Dr Susan Mary Stocklmayer
Australian National University

Date & Time : 13 August 2003 (Wednesday), 11.30am – 12.30pm

1. Content of the paper

1.1 The video presentation showed students' misconceptions of the concept of summer and winter.

1.2 The participants were given hands-on activities to understand why we teach science and the questions that we must consider:

- Why do we need a public that is "scientifically aware"?
- What do we mean by "scientifically aware"?
- How might we achieve this goal?

The responses are:

- For safety
- We are part of the world around us and we need to understand
- We are curious beings and like to find out
- We need to be responsible for the environment
- To use everyday equipment
- To improve standard of living
- To encourage informed decision making
- To understand new issues
- To improve analytical skills

1.3 Teachers are interfaced between science and the public and therefore need to build bridges to better understand the public.

1.4 What determines public attitudes to science?

- A major influence: science in school
- Public activities/statements of 'visible scientists'
- Link between scientists and political, economic or cultural groups
- Direct experiences as consumers, workers or medical patients
- Public controversies, which affect perceptions of the reliability and purposes of science

1.5 However the media influences the public greatly and this may abuse their understanding of science concepts.

1.6 A transmission model relays the message on science concept without a feedback that can lead to the misunderstanding or wrong message on science concept. A better model should have a feedback.

1.7 The science education should address the public needs on science and the following questions must be looked into:

- Who are the public?
- What do we want them to know?
- What do the public want to know?
- Why do they want to know?
- What knowledge does the public value?
- Do scientists share its value?

1.8 The local/indigenous knowledge must blend into scientific knowledge to recognize the common/public knowledge in science. Thus far, the indigenous knowledge has not received equivalent acknowledgement as scientific knowledge.

1.9 High quality learning helps to:

- Discover knowledge for yourself
- Remember for a long time – maybe forever
- See how new knowledge fits in with old knowledge
- Create new knowledge
- Solve problems using this knowledge
- Communicate the knowledge
- Want to know more

1.10 Vision for science education – teaching science in a meaningful and interesting way can lead to better understanding of science concepts.

2. Discussion

1.1 Dr. *Azian T.S. Abdullah* from the Regional Center for Science and Mathematics asked whether the science curriculum should be issue-based rather than content-based.

Answer
We need content to teach issue but can work the other way around by using content to relate the science issues and this will make the learning more interesting. However we must also think upon our system that stresses examination because pupils need to progress in the education system. It is good to allow pupils to explore and understand science by allowing experimental learning.

2.2 *Prof. Khadijah from National University of Malaysia* requested comments on the need of Science (UKM) for research, economic growth and to manage our lives.

Answer
We have to ask what are the country's goals. Why are we doing it? Science is needed most for economic purposes and to satisfy the need of the people. That is where we should begin in constructing the science curriculum.