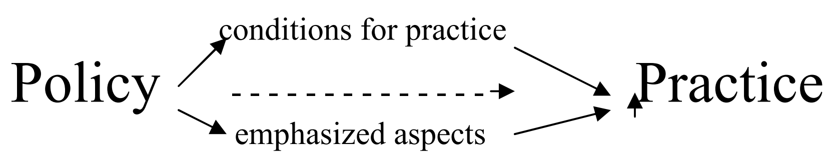
Keynote address for NARST Conference, Baltimore, April 1, 2008

**The Link between Policy and Practice in Science Education:
Where does research fit in?**

Introduction

Researchers in science education very commonly study current practices in science classrooms. They also explore practices that might become part of the wider repertoire of classroom practice. If these research studies reveal shortcomings in present practice or significant improvements in practice, in what ways should we as professionals be concerned about how such findings are heeded by those policy makers, who set the boundaries of how and what is practised in the name of science education.

Policies for education, and science education more specifically, influence the practice of science education by authorizing some conditions for practice of practice over others, and emphasing some aspects of the ***What*** and ***How*** of science teaching and learning.



For example,
A policy that classroom learning in science is assessed by an authority beyond the school, using paper and pencil methods, has clearly different effects on practice from *a requirement that requires schools and their teachers to provide this summative assessment internally.*

Under the former policy, those few aspects of science learning that can be assessed externally will inevitably be given greater emphasis

Again, funding policy, as in Scotland and Japan, that gives a school several laboratory technicians, leads to a greater likelihood for hands-on inquiry learning than is possible *under funding that provides no such supporting conditions*

Policy studies have never been high on the agenda of science education researchers. Richard White in the most recent **Handbook of Research on Teaching** (AERA, 2001) analyzed research studies in science education over several decades. Despite the breadth of his 45 categories of study, policy research was not featured. The same **Handbook** had 51 chapters to cover the whole field of teaching and only two chapters were listed under *Policy Studies*. In neither of these was there any example give from science education, but as I shall refer later to some comments by these authors that have considerable relevance to our concern in this lecture.

Two research handbooks more specifically for science education also yielded blanks about policy research. One edited by Dorothy Gabel for NSTA and the other by Ken Tobin and Barry Frazer reflect very well the foci of what our interests as researchers have been, but again neither had a section on Policy. In the Tobin and Fraser **Handbook** the authors of the three papers on Curriculum Change and Reform remarkably managed to avoid making any reference to the word "Policy". Finally, in the last two years of JRST, only one paper out of more than 100 addresses policy issues and one guest editorial draws attention to its importance.

It is, no doubt, because of the low profile we give to policy issues, that there is not a symposium at this meeting on:

Policy	*impact on*	*Practice*
NO CHILD LEFT BEHIND	⟶	Science Education in Districts and classrooms

Glen Aikenhead (2004), a researcher who has effected changes to policy and practice in Canada, commented:

In research we are able to treat policy, practice and assessment as discrete subject fields for study. If research is to contribute to changes in practice, all three have to come together in some orchestrated fashion.

How this coming together can happen is the task I have set myself for today.

Political naivety in science educators and science education researchers.

Science education has a rather spectacular record of being naïve about policy, educational politics, and the politics of science education itself. Three aspects of our naivety are:

1. development of new Curriculum materials
2. exaggerating generalizability of findings
3. not recognizing the contested nature of Science in the curriculum

1. In the 1960s the National Science Foundation in USA and the Nuffield Foundation in England poured hitherto undreamed of financial resources into developing long overdue new approaches to the teaching of school science. Neither of these countries, at that time, country had a national curriculum, and curriculum policy and its implementation were decentralized to more local authorities. The exciting and very expensive development of these new materials for school science thus took place in the absence of any commitment that they would be adopted and used in either country's schools. It was as if the scientists and science teachers working on these projects simply assumed that the sheer quality of their products would ensure their adoption . Dinted national pride re the authority of Science could ensure these funds becoming available, but it was quite delusory to think that the same authority would hold sway in the much more complex worlds of elementary and secondary schooling.

In fact the excellence of these new materials was no market match for established materials, such as that series of texts in North America from the 1940s, the publisher of which had cleverly appropriated the perennial adjective "Modern" in their title – **Modern Biology, Modern Chemistry** and **Modern Physics.** A common educational policy in the USA that required schools, rather than parents, to provide text books was a condition that also weighed in favour of the existing texts, rather than the expensive new ones.

Indeed, the uptake of these NSF and Nuffield materials was more substantial in a number of other countries and states where centralized curriculum policy existed. In my own Australian state of Victoria every physics teacher and physics student used PSSC Physics for more than a decade.

Not so long after these materials became available, political sociologists on both sides of the Atlantic (Bowles, Gintis and Apple in USA and Young and Jenkins in England) concluded from their analyses that these curriculum development projects took place *as if school science occurred in a political vacuum.*

In 1978 I worked at the University of Illinois when Robert Stake and Jack Easley were editing the **Case Studies in Science Education** – a set of a dozen qualitative evaluations of the NSF's many projects. All too often it was reported in these case studies that these new science materials arrived or were announced in school districts and schools when reform of their science teaching was not near the top of their agenda of issues to deal with. In that same year, an international meeting in Israel reviewed the wider impact of the new approaches to science education that the NSF and Nuffield initiatives had inspired in many other countries. So many reports of disappointing voluntary uptake and unauthentic adoption were forthcoming that Miriam Ben Peretz and Michael Connolly, perhaps with tongue in cheek, proposed the idea of "*Curriculum Potential*". That is, that authentic adoption is not the measure to use, but rather that individual teachers may be inspired by something in the new materials or the ideas behind them to change their practice positively, albeit in ways unpredicted by the developers.

2. The next naivety is quite rife among science education researchers. It is our tendency to claim more for our research findings than they are possibly worth. Recall how many times you have read such a claim in the almost mandatory section at the end of publications that refers to ***Implications***. Jenkins (2004) pointed out how often we fail to see that the narrow scientism behind much of our work has serious limitations in the face of the complex realities of science education across educational systems schools and across countries. For example, a single study, often with cooperating teachers in a particular context in New Zealand, Israel, Germany or USA, is claimed to have implications for schools and science teachers in unspecified other places, that is wide generalizability. This, is not at all to decry the worth of the studies as pieces of research or research training, but rather to be realistic about their generalisability. The critique now becomes much science education research takes place *as if school science occurs in a political and cultural vacuum.*

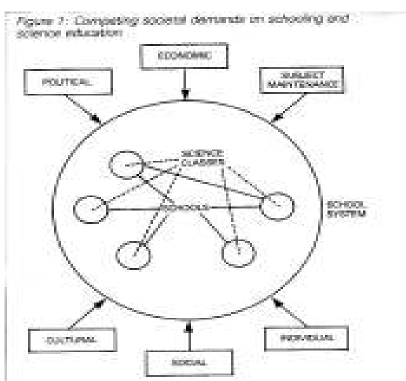
3. As long ago as 1973 David Layton had described a fascinating tale of political contestation with respect to science in schooling. In this historical study, published as a book, **Science for the People** (London: Allen and Unwin) Layton takes us into the tensions that arose when a teacher and a science inspector tried to introduce some science teaching into an elementary school in mid 19th C England because of its relevance to their future as farm laborers. Engineers and earth scientists were unsupoortive because they were busy exposing fossil bearing rocks in the cuttings for the railway tracks to crisscross the land. The last thing they wanted was for schooling to involve them in the furore that Darwin's Origin of Species had created. Then there was shock and alarm at the thought that working class lads may be given knowledge that was not at that time part of the education of their upper class masters, etc., etc.

Whenever, "historical" case studies of curriculum issues in science education have been undertaken they confirm the depth of its contestation. The studies by Jim Gaskell and David Blades in Canada, Rod Fawns and Christina Hart in Australia, Edgar Jenkins and Jim Donnelly in England, Leif Őstman in Sweden, and Dorothy Nelkin in USA, have each extended our understanding of how policy decisions about the science curriculum are made. The tragedy is that they remain far too few and that their worth has not yet been sufficiently recognized in the communities of science education research.

Figure 1 schematically presents the contested character of the school's science education

THE SCIENCE CURRICULUM

A highly contested arena with multiple stake holders



In the 1960s it was the *Political* demand that fuelled the efforts of the NSF. In 1983 **Science for all Americans** explicitly acknowledged ***Economic*** demand in comparison with Japan. Currently, China and India fuel *Political* and *Economic* demands in USA. *Subject Maintenance* is exercised by many academic scientists and conservative science teachers. The top three top demands usually carry much more weight in determining the detail of a curriculum's content and its assessment, than the lower three. These latter are often given prominence in the preambles to a curriculum as some sort of consolation prize. The research community puts a great deal of effort into studies that relate to the lower three demands. The urgency that is now associated with some environmental issues like global warming and the shortage of potable water have such massive economic associations that *Environmental* demand needs to be added to this picture of competing demands.

The interplay of these demands can lead to policies for science education that are very different depending on whether the focus is on the next generation of scientific experts or on the scientific understanding of the public at large. The needs of these two groups in schooling are urgent questions for research.

Policy and Values

Policies in education, as in any other sphere of social life, are operational statements of values. Indeed, as Kogan (1975) argued, an educational policy authoritatively allocates values. Hence, *values* and *authority* lie at the heart of our exploration of the link between policy, research, and practice. Two sets of questions immediately arise when we think about general and specific educational policies and their impact on the practices of science education.

Set 1: Policy as Values

Whose values about science education are favored by this policy?

Which stake holders in society have been successful in the shaping of this policy?

Which groups in society will be advantaged and which disadvantaged by the science education practices that flow from this policy?

Are disadvantaged groups favored in our studies of practice and would others be disadvantaged if policy was framed to support our practices?

These questions are indicative of a large agenda for research.

Set 2: Policy as Authority

Where does authority lie in relation to this policy?

Which stake holders have access to this authority?

Where does the authority for practice lie?

By whom and how is the link between policy and its intended practices monitored?

Again, all of these questions are amenable to research, but this type of research is still very rare in science education. They will also often require methodologies rather different from the range we now commonly draw from.

The locus of authority for science education

In 1978 I also conducted a small study of persons who had worked in these development projects. It resulted in a simplistic paper entitled *Textbooks, Teachers and Committees* in the **European Journal of Science Education** (1981). In it, I argued that the determining authority for the curriculum in practice in USA, Europe, and Australia was, respectively, the Textbook, the Teacher and the Education System's Curriculum Committee (made up of academic scientists and their acolytes, leading science teachers).

Much later, in the 1990s, I had the opportunity to penetrate more deeply into this location of authority. This was an outcome of the discussions between scholars in North America and scholars in Germany and some other European countries about the role of subject content. The spur for these discussions was the identification of Pedagogical Content Knowledge (PCK) by Lee Shulman his presidential address at AERA in 1986 and his elaboration of it in the years that followed. These discussions were very important in providing a bridge between two different educational traditions that for years had been kept apart by the adjective, *didactical* in English (that carries negative connotations for teaching) and the German noun *Didaktik* (and its other language counterparts) that carries profound meaning in education.

I will share in a simplified form a few significant differences that result from these two traditions which for convenience I shall label, AngloAmerican and Germanic. Rather crudely these different philosophical approaches to schooling can be stated as inducting the learner into established bodies of knowledge (AngloAmerican) compared with drawing on knowledge sources to develop the whole personality of the learner (*bildung)* *(*Germanic). This difference is illustrated in Figure 1 where the locations of key elements of the authority in each system for what is taught, its teaching and its assessment is shown.

"Curriculum"	"Didaktik"
AngloAmerican tradition	*Germanic tradition*
Education System	Education System
establishes	*defines purpose of schooling and knowledge sources*
Curriculum Authority	**Teacher**
details science content for teaching and learning and the mode of assessment	*transforms source knowledge into knowledge for schooling*
Teacher	
chooses pedagogies	*chooses pedagogies and*

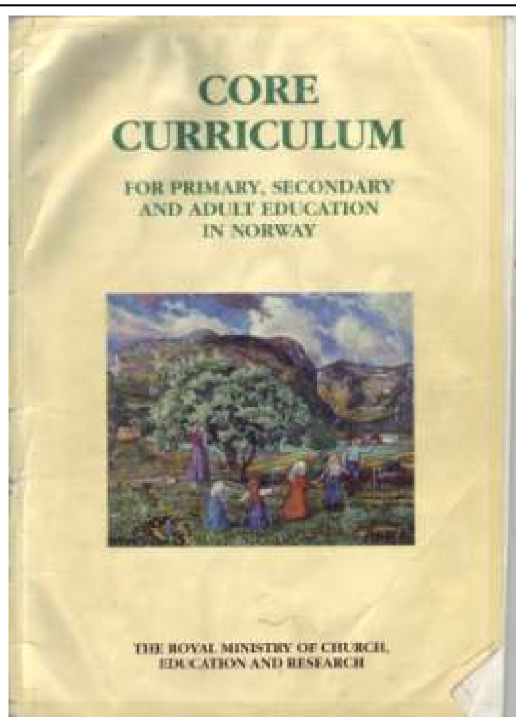
Figure 2. Some different locations of authority in two educational traditions

In cases of the Curriculum tradition an obvious focus for policy research is the *Curriculum Authority* and how it is established by the Education system. Conversely the *Teacher* and his/her sense of authority re the content to be taught and learnt and the processes of changing them is a place to start in the Germanic tradition.
Calderhead (2001), writng in the AngloAmerican tradion, commented that *policy makers view teachers as implementers of other people's ideas, without recognizing that they have developed considerable knowledge and expertise of teaching and learning and of the ways that classrooms and schools can and do operate.*

An interesting example of the outworking of these two traditions is to be found in the reforms of science curricula that occurred in the 1990s following the calls for Science for All in the 1980s.

In Australia, as in many English speaking countries, new policy defined the school curriculum in terms of Key Learning Areas – eight familiar subjects and subject combinations - into which was fitted what was to be taught and learnt. In the same year the Norwegian Parliament passed into law the **Core Curriculum** as the policy document for education at all its levels.

This **Core Curriculum** must be the most beautiful educational policy document ever. It is illustrated on every page with colour art works, and its language in Norwegian and in English has a resonant cadence similar to the Bible or Shakespeare.



I understand it was personally written and the illustrations chosen by the Minister of Church, Education and Research, a man (who was earlier a Professor of Sociology at Harvard) in the Bruntland Cabinet with its majority of women.

(How the associations that governments put together with Education effect their policies would, I fancy, be an interesting study. Education and Sport (The Philippines), Education and Science (England and Wales), Employment and Work Place Relations (Australia), Church, Education, and Research (Norway), etc. would be an interesting matter to explore.)

The sections of this document do not refer to subjects but to purposes and intentions for education, and hence in some way for science education and all other components of teaching and learning.

The Core Curriculum

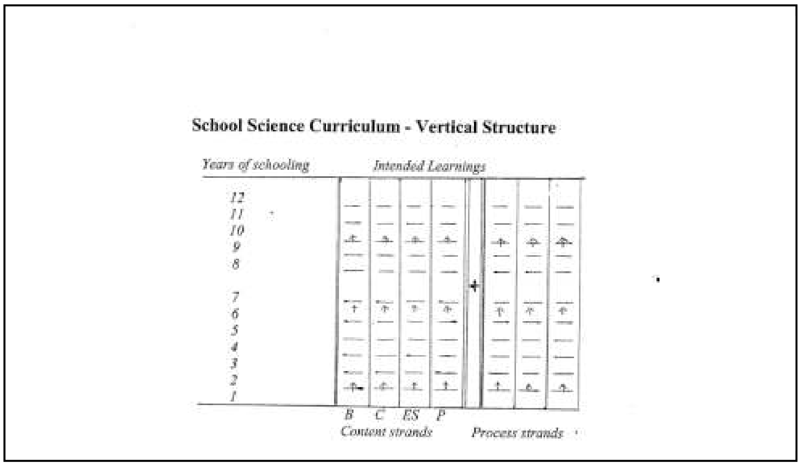
Norway, 1994

- The Spiritual Human
- The Cultural Human
- The Working Human
- The Socially Conscious Human
- The Creative Human
- The Environmentally Aware human
- The Integrated Human

The **Core Curriculum** is curriculum policy at the grand level. As policy for science education it may also take the prize for the least influential policy document as far as science education is concerned. The gap between its lofty phrases and the classroom teaching of science is so great that it is hard to see how that practice could have been much affected. I became aware of the size of this gap when I was employed in Oslo to search my experience of science teaching in various countries in order to annotate the **Core Curriculum's** pages with examples of science education that could conceivably be connected.

Policy for the structure of schooling

The AngloAmerican tradition of teaching subjects that are specified beyond the school fits neatly into policy that presents the structure of schooling in a vertical fashion. The whole of schooling and the science curriculum, in particular, are seen in terms of a vertical structure stretching from Grade 1 to Grade 12.



This vertical structure readily accommodates long ladders of learning of content knowledge from the major sciences plus some sequenced attention to scientific processes. Their content for learning is set from top to bottom or bottom to top in some logical fashion for each discipline. It is natural within such a vertically structure that their will be a recurring research interest in *Scope and Sequence* or in *Progression in Learning,* that I notice is again a research focus at this conference. This structural view of schooling, of course, also builds in a high probability of failure at some point up these ladders, which only an élite group of students will have the stamina and inclination to keep climbing.

This vertical policy denies science education the chance to meet differential needs of students as they move through schooling and later the needs and interests of different groups of students at the same level. I could argue it has much to do with the elusiveness of Science for All.

When the same years of schooling are thought of as an horizontal structure, it is immediately evident that this is more conducive to a science education that is primarily about the needs and interests of the learners and how these change as the learners get older.

In such a structure the early years can be devoted to extending the curiosity young learners bring to school by exposing them to a rich set of natural phenomena where their main goal is to ask questions and begin to recognize the different ways, including scientifically, they may be explored. This would be a welcome alternative for elementary teachers who now feel obliged to teach answers to questions their children have not asked and concerning which they themselves are not very confident.

The idea of a curriculum with different curriculum emphases for Science, that Douglas Roberts in Canada spelt out in 1982 and 1988, makes very good sense in such a horizontal view of schooling, and is well worth a revisit.

Positive examples of Policy to Practice

General educational policy

A number of science education researchers from the University of Maryland and from Monash University were privileged to work with the Institute for the Promotion of Science Teaching in Thailand when that country began in the 1970s its curriculum overhaul, a decade after many others had already completed the 1960s phase.

One policy decision in Thailand had a remarkably direct effect on student learning. It was the requirement in senior high school that students in the ‘science stream’ of studies would study Physics, Chemistry and Biology for three years. The uptake into this ‘science stream’ was further encouraged by the requirement that students taking the other ‘humanities stream’ had also to take two years of Physical and Biological Science. As a result, at least in the very large Bangkok metropolitan area, Thai girls and boys were the first in the world to participate and perform equally in Physics, while in Chemistry the girls significantly outperformed the boys.

When questioned about why these policy decisions had been made, the answer was given: “We heard countries like yours were having difficulty persuading girls to choose Physics and Chemistry, so we made them compulsory along with Biology.
After all, the girls can’t perform well if they are not in these classrooms!!”

Introducing a policy of “no choice” in senior high school was culturally possible in Thailand; but such a policy would be impossible in the senior high years in Australia, (and I suspect, in USA) because of our strong cultural belief in “choice”. But belief in choice in the higher levels of schooling has the inevitable consequence of less choice of courses to study at university and less career possibilities. Research that clearly documented these consequences was carried out in the 1980s but it is probably an issue worth revisiting with a wider than gender only sense of disadvantage.

In that period of international educational development in science and mathematics, Thailand was interesting and different in its capacity to link policy and practice via the requisite conditions that encouraged faithful implementation.

Specific science education policy
One of the paradoxical aspects of relating research in science education to practice is the tradition in many countries, but not all, that the how of pedagogy is determined by the teacher. What is to be taught is more regularly prescribed in the AngloAmerican tradition by authority beyond the teacher as a result of the contestation described earlier, but the how of its teaching is the teacher's province. Against this recognition of teacher professionalism stands the fact that much research in science education is about teaching practices that will lead to more effective learning. These are often innovative in the sense that they are being explored by a researcher and cooperating teachers. When a positive effect is found, what then is the researcher's role with respect to other teachers who have not been part of this exploration and whose students are thus not having the opportunities that the treatment classes had. In what sense should there be small scale policy about how teachers teach? Such small scale determination of how teachers teach is regularly exercised through the pedagogical skills stressed in teacher education and through emphases in externally controlled assessment procedures.

A case in point in science education was reached in the late 1980s with the many studies in a variety of countries and classroom settings that reported that *concept mapping* was a very good tool for students to use to consolidate the learning of the relations between science concepts and the links between these concepts and everyday phenomena, etc. Some of us in the Australian state of Victoria pressed this point so strongly that it became part of the policy for a new chemistry course that all students should be given the opportunity to practice concept mapping. *Concept mapping* became what was called in the state's curriculum a *Work Requirement*, which meant it had to be practiced by all chemistry teachers with their students. Another less contentious *Work Requirement* in senior Physics and Chemistry was *An Extended Open Investigation,* which also by this time had strong research support for contributing to the student's appreciation of the nature of science.

I wonder which pedagogies for science education could now be added to *concept mapping* and *open investigations* as having such positive research outcomes in so many contexts that they should be recommended for general use by teachers. In their national contexts of these research studies, should NARST and other similar bodies then strive to have established as policy that they be a priority call on professional development time and resources so that they can be required of all science teachers. I suspect a small, but important list of pedagogies would emerge.

International assessments of science and policy

The current two big international assessments of science learning, TIMSS and PISA, both measure student science learning performance, albeit very differently, conceptually and methodologically. TIMSS is an assessment of intended curriculum learning in science at ages 8 and 14. It is severely constrained by being able to include curriculum topics and emphases that are common to its many participating countries. PISA, on the other hand has a very different charter.

ORGANISATION FOR ECONOMIC COOPERATIVE DEVELOPMENT

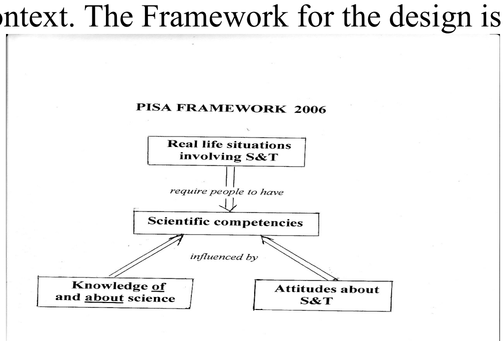
Programme of Student International Achievement (PISA)

- *To provide information (representative, valid and reliable) to member countries about how well their 15 year olds are prepared for life in the 21st C in Reading, Mathematics and Science*

- Note it is not a test of school learning in these three fields

To meet this goal the Science Expert Group for PISA has focused on students' ability to actively use their Knowledge of Science and Knowledge about Science in novel situations that are real life examples of science and technology in 21st CD life. It is not concerned with the students' passive store of scientific knowledge or its applications to the familiar and contrived situations so common in text books or science examinations.

The design of the PISA test begins with a description of a real world S&T situation or context. The Framework for the design is represented in the diagram.



In PISA 2006 three scientific competencies are measured – *identifying scientific issues, explaining scientific phenomena*, and *using scientific evidence.* Each of these is an aspect of the scientific literacy it has defined for the task of measuring the preparedness of students for life in 21st C. They will in turn reflect the students' scientific knowledge and attitudes towards S&T issues.

Each of these projects also collects a large amount of data that can be used to derive measures social constructs that have been judged likely to influence the students' performances. The management groups of the projects, the I.E.A and the OECD, claim that their projects and especially the interactions of these two sets of measures will lead to policy implications for the participating countries. In fact, despite the considerable contextual data that each project collects these interactive policy implications remain, in my opinion, largely of little use to science educators.

For example, the PISA results for scientific literacy in Australia are related to the index of economic, social and cultural status (ESCS) of the student's family background (one of the more robust of the contextual measures). On average Australian 15 year olds performed very well, but they also manifest a higher socio-economic gradient than some other countries including those which have higher mean scores. This socio-economic gradient means, for example, that almost one quarter of the students from the lowest quartile of ESCS background performed below Level 2 (out of 6 levels) compared with just 5% of the students from the highest ESCS quartile. At the other end of science performance 26% from the highest ESCS quartile performed at level 5 or 6 compared with just 6% from the lowest quartile.

Such results are consistent with 20 years of government policy about schooling that has encouraged socio-economic segregation of students, although this government policy is not part of the data collected by the PISA survey instrument. Such a national policy's impact on science learning is profound and important but it is beyond the reach of science teachers to rectify. The very recent change in our national government has heralded an 'education revolution', and it will be interesting to see if this includes any serious attempt to enunciate and enact new policies about greater equity in Australian schooling.

The relative mean performance of the students' scientific literacies across the participating countries attracts more attention than it should, since what PISA is measuring as scientific literacy may not be a priority in a particular country's curriculum. More interesting are the patterns of cognitive and affective achievement that emerge from the data when gender is considered In the first of these girls in almost every country out perform boys. In the second boys usually outperform girls; while in the third there are few significant differences. Similar striking patterns of gender differences can be found in the students' responses to affective questions about big environmental issues facing so0ciety today. Such persistent patterns do raise policy issues for public understanding of science.

A very frustrating aspect of the TIMSS and PISA findings, from a policy point of view, is that the variance in students' scientific literacy in many countries is split 20% *between schools* and 80% *within schools*. ESCS backgrounds and schools' resources and conditions account for most of the *between schools* variance, but the much larger *within schools* variance remains quite a mystery.

I remain strongly committed to the importance of the OECD's PISA Science study because of its innovative definition of scientific literacies, and because it uses modes of assessment that are still novel or unknown in most of the participating countries. I have, however, now concluded that the positivistic approach in both PISA and TIMSS to measuring the contexts that influence science learning has led to very little of value.

Furthermore, as Svein Sjøberg (Norway) and Masakata Ogawa (Japan) have recently pointed out findings from projects like TIMSS and PISA, that have such an internationally authoritative ring, can be very misleading when it comes to their implications for science education in any given context. In every country the teaching of science (and indeed the whole of schooling) takes place in ways that have a long and firmly established cultural history. It is quite inappropriate to pluck some feature of a higher performing country and imagine it can be simply transplanted into another educo-cultural setting. Rather the comparisons these international studies reveal are better used as stimuli to reflect on which policies in one's own educo-cultural setting might be responsible for its performance and whether different policies could lead to improved performance.

In USA you were treated in the 1990s to a flurry of simplistic comparisons of the findings from the TIMSS study. Almost every issue of **Phi Delta Kappa** for several years carried articles by G.W.Bracey and others, which on the one hand derided the worth of the TIMSS study and then took its findings seriously identifying variable in other countries as salvation possibilities for America.

Other misuses of research to influence policy

Policy makers have a tendency, when they do use products of research, to do so when it supports their own ideas, and they ignore other contributions that research might make (Calderhead, 2001).

Too often they get away with this because this usage is not challenged by the researcher or his/her research community. I expect you will be all too familiar with this tendency. In Australia, findings from the conceptions research, so popular among science educators around1990. have been used recently as policy support for the inclusion of more conceptual science content in the elementary years.
Other more recent research findings point to this type of content, so early in schooling, being a cause of the attitudinal malaise about science we are now experiencing.

Research to support a change in policy and practice

It is not sufficient to establish from research that an innovation is worthy of policy support. It is most important that research studies have also established the weaknesses in the out-workings in practice of the current policy. That is:

CURRENT POLICY	*argument for change*	**PROPOSED POLICY**
research-based case of its inadequacies		***research-based case for its positive prospects***

Queensland where I now reside is an educationally interesting state in Australia because it is the only state that has no common state wide examination for graduation from high school and for selective entry to university. Accordingly it is the only state in which it is possible to have some schools undertaking an alternative curriculum as a trial. Over the years when dissatisfaction with an existing subject curriculum has reached a certain level, a decision is made to develop and trial an alternative one.

2007 was thus the end of a several year trial of a *Context-based Chemistry* and a *Context-based Physics* course in a small, but significant fraction of Queensland schools. When these trials were evaluated, it turned out that the focus of the research evaluation of the trials was on difficulties the trial teachers had had with this novel approach to their subject. In other words, the dissatisfactions with the mainstream courses, that were the original reason for these trials, were forgotten. Only strong reminding of these dissatisfactions staved off a decision to abandon this trial.

Linking Policy Options to Research

Early in 2007 I was invited by UNESCO to prepare a *Draft Policy Options Paper* for the World Conference of the International Council of Associations for Science Education, the umbrella organization for bodies of national science teachers like NSTA. Although long interested and involved personally in policy aspects of science education and of education more generally, I had not before written about policy options in this explicit way. I think that carrying out this task taught me some important things about linking research to policy, and these may be worth sharing.

I decided to take a number of contemporary issues in science education and briefly outline their present character (in national contexts with which I was familiar) including inadequacies and that have been revealed through research studies. The final set of issues is listed in Table 1.

Table 1. Science Education Policy-making
eleven emerging issues

A. Access and equity in science education
B. Interest in and about science
C. Science in school and its educational purposes
D. How Technology relates to Science in education
E. The nature of science and inquiry
F. Scientific literacy
G. Quality of learning in science
H. The use of ICT in science and technology education
I. Relevant and effective assessment in science education
J. Science education in the elementary years
K. Professional development of science teachers

Each of these issue headings made sense to policy makers, but I quickly realized that they were each so multi-faceted that that no single research study could possibly be quoted as definitive, about either the status quo of the issue or of a change in it that could justify a policy shift. Nevertheless, by drawing as widely as I knew on the research literature, it was possible to come up with a set of findings that, together, made a case for the inadequacy of present policy and another case for positive prospects from a policy change Policy makers are not researchers so they are not impressed by long lists of references. The case for change, and the case for any proposed policy options, need to be made forthrightly in plain prose, that can be supported under questioning by the relevant research studies. In the *Draft Paper* under each issue I set out a list of the likely advantages and the probable disadvantages that went with each policy option.

The organizers of the World Conference established an excellent process for the 1000 plus delegates to comment on this *Draft Paper*, and for the 100 plus who were more involved or more interested in science education policy to critique it in small groups. UNESCO in Paris then invited me to revise the *Draft* in the light of these quite detailed recorded comments. The scope of the issues was extended, along with the accounts of their present state and inadequacies. There was strong advice that the status quo of an issue should not be offered as an option. Furthermore, it was suggested that rather than the advantages and disadvantages that could follow such a policy option, it was more important to list the concomitant changes in conditions that would be needed to ensure implementation of the new policy as intended. Too many policies have been announced and failed to have impact, because these concomitant changes in condition have not been recognised or supplied.

The revised document is thus based on:

	a*rgument*		*conditions needed*
CURRENT POLICY	*for*	**PROPOSED POLICY**	*for implementation*
	change		
research-based case of its inadequacies		***research-based case for its positive prospects***	

Responsibility for linking research to policy

The sources of policy in education, and in science education more specifically, are so often other than research that is common for policies to be announced and instituted that actually fly in the face of research findings.

Who should be responsible for pointing this discrepancy out?

It is not uncommon in other professional fields for their organization to ask a small group of members to be alert to proposed and actual new policy formulations and to critique them from some agreed criteria. For example, I knew the chair of such a group within the Town Planning profession who had responsibility of asking about each new planning proposal: *What impact will this have on women?* Planning decisions so often in the past had benefited men?

As science education researchers our criteria should clearly be based on our research knowledge, and what it points to as likely, rather than certain outcomes
.
Our overarching question could be: *What will be the likely consequence of this policy on the quality of science teaching and learning?*

This question is not something an individual researcher can easily take on. Nor is it really appropriate for one person to draw up the research-based cases needed to recommend a shift in policy, as I tried to do for UNESCO. They involve the findings from a number of studies, and are more likely to be complete and convincing, when drawn up by a group of researchers than by any single researcher. This raises the issue of who should constitute this group. An obvious body is a research association like NARST in USA, ESERA in Europe, or ASERA in Australia and New Zealand.

A guest editorial in **JRST** in 2006**,** by Pamela-Fraser Abder, Mary Atwater and Okhee Lee drew attention to the need for just such a set of research-based information that would guide policies for reducing the science achievement gaps in urban schools. In 2007 Penny Gilmer, in her presidential statement, was eager to bring the issue of policy making before the NARST community. In this lecture, I have tried to provide a platform for discussion within this research community and other ones in science education for what such involvement could mean.

In the last part of this lecture I wish to speculate on what the terms of reference might be if NARST Council was to ask its Standing Committee on Policy and External Relations it to take on a more proactive role.

1. *It should be asked to set criteria, based on research findings that have a probability to predict likely outcomes from any suggested or established policy in education or in science education specifically*
2. *It should monitor existing policies with respect to their role in facilitating or inhibiting quality science education, and recommend review or amendment where inhibition is found*
3. *It should scrutinize any proposed new policies from the viewpoint of their likely impact on the quality of science education, and which groups of learners in society are most likely to benefit and which will be further disadvantaged*
4. *It should be proactive in choosing each year one or two large issues in science education, bring to bear on them the relevant research studies and, on that basis, propose new policies that could move these issues on.*
5. *It should have the power to co-opt temporarily researchers with expertise in relation to a particular policy or issue.*

The Committee on Policy would then:

- report annually to the NARST community,
- in relation to its chosen special issue be responsible for a Symposium at the annual conference that illustrates how research can be related to policy.

- make recommendations to NARST Council for it to act accordingly to the appropriate authority.

Our colleague professionals in the Sciences and Engineering expect and have their research heeded, and they and their organizations challenge public policy when it flies in the face of their established work. If, as a research community of science educators we value our own research, the issue of how it can be used to influence policy and hence, practice, must, I believe, be urgently addressed.