I keep six honest serving men

Peter Galbraith
Graduate School of Education, The University of Queensland

" I keep six honest serving- men
(They taught me all I knew);
Their names are What and Why and When,
And How and Where and Who. "
(*Rudyard Kipling*)

In compiling thoughts for a plenary address such as this, a variety of personal choices present themselves. If I was to choose my own work as a focus then that would probably mean that ninety percent of any audience would be marginalised as far as their individual interests were concerned. Those interested in that work know where to find it and for present purposes I am happy for it to rest there, and in related conversations. I will, however, draw from experiences to illustrate some of the issues I hope to engage.

A paper such as this should reflect to some degree the joy of living and share light hearted aspects of our common endeavour as we face the challenge of teaching mathematics in new times. It should also draw the presenter to elements that make him uneasy and concerned, and these aspects also should be shared with the listenership/readership.

There are two risks with this approach. One is that avoiding specialization runs the risk of superficiality. The other is the risk of sounding like a preacher when the intention is rather to interrogate and question. We shall do our best.

Before commencing the text proper I should like to introduce an unseen presence. This presence is the 'ghost' of a child of the future. She is 10 or 15 or 20 years old, the year is 2010 or 2030 or 2050, the detail does not matter. What does matter is the single question she asks of each of us:

"What did you do in your academic lifetime that has helped make my mathematical education better than it would otherwise have been?"

We shall return to her from time to time, but now to work:

"In the High and Far-Off Times O Best Beloved ..... there was an Elephant's child – who was full of 'satiable curtiosity', and that means he asked ever so many questions."
(Kipling, 1903)

Following this theme from one of the Just-So stories, I want to structure our excursion around Rudyard Kipling's six honest serving men. That is, I intend to share a personal response to the reflections generated when these questions are put within the field of Mathematics Education research and practice as we look forward at this point in time.

'What' Questions

To obtain a sense of 'what' is exercising our global community at the present time, I sought to summarize and classify the Short Communications written in English(500+) that were presented at ICME 8 in 1996. Because such work represents grass roots activity, it may be more indicative of total action than more selective journal publications. Of course, decisions on classification are to a degree subjective, and many presentations involve more than one focus but the following distribution emerged with the categories decided empirically from the content of the material, not pre-determined.

A. Major categories by number (influenced by my decisions to combine types)

- Teacher Education and Professional Development

- Technology
- Problem Solving/Modelling and Applications
- Metacognition/Constructivism/Collaborative Learning
- Gender/Social Context/Ethnicity
- Affect/Special Needs
- Geometry/Proof and Reasoning
- Number/Algebra/Calculus/Functions

B. Categories with Substantial number of entries

- Assessment issues
- Competitions/Materials/Texts/Games
- National Contexts/Political Content
- Probability and Statistics
- Tertiary Mathematics Topics
- History/Philosophy/Aesthetics

It is interesting to note that the two most populated categories were in fact Teacher Education (the human element in teaching) and Technology (the non-human element). Beyond that observation, what seems to be clear is that there is continued and intensive action somewhere on all the fronts that have provided recent foci for research and development activities, and as are represented for example in Research in Mathematics Education in Australia 1992-1995.

So what are some of the sub-themes that emerge from such an exercise. One is linked to the number of studies that continue to be generated in such basic learning areas as number, fractions, decimals and beginning algebra? The number of individual studies that can be designed appears to know no bounds. A question for our community is the extent to which studies on a given topic lead to isomorphic results – that is they say the same thing but are dressed in different clothes according to context. What might meta-analysis show that could provide stepping stones to a new level rather than adding to a maze of paths at the same level?

Secondly, what needs to be done to extend the power and applicability of conceptual frameworks such as information processing theory? Some few years ago I was talking with Gila Hanna when she lamented along the lines that:

> *"In the late seventies we were excited about understanding applications to learning such as 6 + 8 = 14 etc. What are we doing now (well over a decade later) – still looking at 6 + 8 = 14!"*

The point was not to talk down the importance of research in early number learning – it was to lament that we continue to take the easy option. That is- to look for mathematics that easily fits a theory rather than engaging the more challenging problem of extending theory to domains that lack the convenient discrete matching that operations, whole numbers, and simple symbols provide for processing models. And how many different IP theories are themselves isomorphic?

Thirdly, what tensions remain either unidentified or avoided within our research field? A clue is obtained by reviewing the substantial range of studies that fit within the description of Tertiary Topics. It was observed that with some few exceptions there appeared to be minimal interaction between the two components of our discipline; Mathematics and Education. Most tertiary topics were presented apparently free of learning contexts or implications. On the other hand, some of the presentations on learning mathematical topics at other levels, seem to be relatively innocent of concerns for the quality of the mathematics. So we are still in a socio-cultural situation where parts of our community are not communicating with each other. Put another way, the challenge remains to spell our discipline with a capital M and a capital E, not with one or the other or both in lower case. That this issue is of continuing importance was emphasised again as recently as April through an e-mail received from Mogens Niss:

> *"I have been invited to give a 45 minute talk in August at the International Congress of Mathematicians, in Berlin, on the nature and state of research in*

Mathematics Education, in particular as far as results are concerned.... It was not an easy matter at all to make ICM place Mathematics Education research in the program. I am planning to present a number, say 10, of major (and substantiated) findings in Mathematics Education research in a way that allows me to also discuss why a finding is neither a theorem, nor an experimentally verified result in the sense of, say Physics or Chemistry, but nevertheless something that represents deep reasoning and empirical analysis giving rise to insights of considerable significance to our understanding and development of teaching and learning of mathematics."

Interestingly within this vein a hopeful note sounded as a result of the ICME analysis. This was the significant number of professional development and teacher education partnerships that involved collaborative contributions from mathematicians and/or mathematics pedagogy specialists and/or professional teachers.

So to summarize: What constitutes new knowledge and what represents re-packaged or isomorphic knowledge in well trodden research domains?
What is needed to enable theories such as information processing to reach the next level of application in complex mathematics learning?

What steps are necessary to increase the power of the partnership between Mathematics and Education in forums where one tends to dominate the other?

'Why?' Questions

Asking why? questions can help clarify reasons for shifts of emphasis within the field such as: Why is that area being abandoned or scaled down? Why are these new directions emerging at this point in time?

Reasons may broadly be classified as social, political, or personal and of course combinations of all three. Examination of some of the 1996 ICME projects is illuminating in understanding the social component. For example, Vandenberg points out the incompatibility of individualised Western approaches to learning within a group oriented African culture; Mel'Nyk from the Ukraine describes why the need to subsist is diverting teachers and students from mathematical study in a traditional centre of mathematical learning; Bhattycharyya notes the incongruence, and questions the relevance with which western computer technology can be superimposed in an Indian society rich in traditional culture!

Political reasons are more obvious, need little elaboration but rather more soul searching. Whether generated as a result of 'colonial echo' (Clements and Ellerton, 1996) or more locally generated by vocational or other contemporary needs as viewed by government they are centrally a locus for 'moral dilemmas' at system and personal levels. Do I accept the edict of political masters and help to make their interventions "work" whatever that means, or do I take a stand on principle when such is at stake, work for the higher ideals which I value, and risk marginalisation as a consequence?

Personal reasons may be subtler but no less influential. Why do I do what I do? To what extent am I swayed by the need for peer approval? I recall reading somewhere for example that "the '80s was the era of metacognition, the '90s the era of constructivism". Does this mean it is no longer fashionable in the 'best' research circles to espouse that which someone has declared yesterday's focus? In Thomas Kuhn's (1970) *Structure of Scientific Revolutions*, he refers to the social circumstances that arise in a community of scholars when a new paradigm challenges the old. While the emerging paradigm creates excitement through the new avenues it presents, a vast amount of "mopping up" activity continues within the earlier approach. This mopping up includes the solution of puzzles as yet unresolved and continues until by consensus no new amenable problems remain. While Kuhn was referring to methods of scientific enquiry, much of the logic translates to the content of activity. A new urgency arrives on the scene – but that does not mean that unfinished business should be set aside when much remains to be done. Our ghost child asks accusingly, "Why did you stop working in an area so central to understanding more about learning and in which so much remained to be done? Why did you abandon us?"

In asking Why? questions the fundamental driving force needs to remain the total enterprise of better learning, wherever that causes us to erect our tent, against the temptation that given the gift of a brand new hammer to see everything as a nail.

'When?' Questions

When do we stand back, reflect on our sometimes-frenetic activity, and ask our colleagues or ourselves uncomfortable questions about assumptions, values, and where our research is heading? For some time I have been involved in project activity associated with the use of technology in both secondary and tertiary settings, and I would like to draw on this orientation for purposes of illustration. Getting a grip on what is happening in technology is rather like trying to control a newly active volcano, as noted by Fey (1989) some years ago and it remains as true (or more so) today. In reviewing reports of technology-assisted instruction, it quickly becomes clear that the meaning given to such activity is fuzzy-so fuzzy and broad in some instances as to be almost useless if not actually misleading when trying to infer effectiveness, as distinct from reading descriptions of practice. The results of a valuable survey of Graphical Calculator research for example, by Dunham & Dick (1994), allowed inferences that were at most equivocal as to effectiveness, with the range of usage reported varying from limited access to integrated activity. Other studies in making very general claims for improved 'attitudes' triggered an 'alert' that it was time to ask targeted questions about possible interactions between attitudes to mathematics and attitudes to computers. In a paper in press (Galbraith and Haines, 1998) we found that among beginning undergraduates, mathematics confidence and mathematics motivation were strongly associated, as were computer confidence and computer motivation but that correlations between the mathematics and computer scales were much weaker. The scores on a computer-mathematics interaction scale correlated much more strongly with those on the computer scales than with those on the mathematics scales. This outcome provides empirical support for maintaining distinct scales for mathematics and computing when attitude measures are of interest, has resulting implications for the introduction of computer based activity into mathematics learning, and for our further research. The 'when' component arises because it is the accumulation of reported outcomes that seem 'not quite right' that eventually trigger the mental stocktake and altered direction. And of course our own findings are no more exempt than earlier ones from similar critique seeking to clarify future research priorities.

Other questions arise when time is taken to reflect on statements and claims made in relation to the impact of technology. One that comes to mind concerns claims made for computational technology in terms of rendering certain types of learning redundant. A case in point is the ability to produce complex graphs using graph plotters or graphical calculators. A popular type of traditional question for a year 12 test paper was to sketch the graph of a quotient of polynomials e.g. $y = \dfrac{x^2 - 5x + 6}{x^2 - 5x + 4}$

Now of course this can be produced immediately by computational means so clearly the purpose of such a question type is obsolete – or is it?

It is arguably so if the purpose was to be able to draw such graphs purely as an end – but no-one would ever suggest that the earlier goal was to prepare a student for a future in which such proficiency was a valued and essential vocational or life skill. Rather, the purpose was to test the ability to integrate information concerning domains, axial intercepts, discontinuities, asymptotic behaviour, and maxima and minima into a coherent whole, for which the graph provided the visible display of understanding. The question here is not whether such a goal is worthwhile (that is a separate debate) – but that if such a goal is valued then the use of computer technology is irrelevant to its purpose, and the resulting product of no educational consequence in this context. The situation is like the

Victor Borge story about the doctor who discovered a cure for which there was no disease!

A third stimulus to the act of review can occur when noticeably different actions and problems emerge in settings, which in other respects contain similar features. This has been vividly illustrated from data currently emerging from two projects involving respectively the use of technology in an undergraduate mathematics course, and in a course located at senior secondary level, in which the author has found it useful to use the descriptors of *power tool* and *learning tool* to describe two different ways in which students use technology. When used as a power tool, students use their computational aid as a self-generated means of solving existing problems and addressing new ones, demonstrating both mastery and versatility e.g. the effective use of spreadsheets. In learning tool mode students may, for example, be seeking to learn new concepts and calculus based problem solving techniques by working through workshop material designed around the use of symbolic algebra packages such as Derive, Mathematica or Maple.

Just how different these properties are has begun to emerge – students struggling with a learning tool are battling a plethora of difficulties, which are cascading and multiplying. Students mastering computing as a power tool are not only using it effectively in problem solving but in some cases re-inventing it as a learning tool for acquiring new skills and knowledge beyond the initial context. And evidence is accumulating that apparent power tool proficiency can flatter to deceive as when superb project work assisted by symbolic algebra software is compared with mediocre (or worse) performance on conceptual material closely aligned to the project content. Computer based learning has traditionally been reported in terms of variations in the computer role; it is now time to give greater attention to the different characteristics that human participants display in terms of the way they interact with given technological environments. Sociocultural theory is promising here as we consider not only the transforming effect of new technologies on human action, but that human action may in turn stimulate new learning possibilities for such technologies.

Questions can also be triggered when accumulating unease about perceived over simplification reaches some threshold level such as misgivings about the over-interpretation latent in the use of metaphor. I recall reading a piece on problem solving in which the game of tennis provided the metaphor. The argument was for immediate involvement in problems without attempting the thorough development of associated skills. The reasonable grounds were that it is possible to play and have some success and motivation with tennis, without requiring that the component shots be perfected first. A balancing observation would be that the substitution of a military or medical metaphor would result in the reverse argument -survival on the battlefield or performance of difficult surgery cannot be left to exploratory chance or semi-developed skill. It is not a question of being right or wrong but a recognition that the use of metaphor is a concession to our inability (due to limited processing capacity) to keep in mind all relevant aspects of a topic or field. What this does at one level is illustrate why different perspectives on a common issue (such as the development of problem solving expertise) continue to attract their respective and at times vehement proponents. What it does in general is to remind us of the potential abuse of metaphor- that is the imputation of objective truth such that the metaphor becomes "fact" and inferences are ascribed the status of logical consequences.

'How?' Questions

Here I would like to ask a different kind of question. How can we, as members of the Mathematics Education community of practice, make our own unique contribution to methodological critique?

As Educators, we are part of a Social Science community, co-existing with or engaging in a world of deconstruction, post-modernism and a variety of other 'isms' that characterize the field. Some of us feel pressured, or obliged, or act by conviction to engage to a greater or lesser degree with these concepts. From time to time I am tempted to remind over-enthusiastic friends that concepts such as post-modernism have the same level of reality as Puff the Magic Dragon! That is not to say that such concepts are not useful or important, but to recognise that they are but preferred frameworks through which individuals choose to interpret their world.

Inevitably, most of us have been involved at some stage with debates about research paradigms, e.g. the validity of quantitative versus qualitative methods, either as research students or as supervisors concerned for the 'academic safety' of thesis students. Interestingly perhaps, the post-modern view has been instrumental in bringing about the acceptance of a wide range of methodological approaches. Whatever the reason, it now seems true that both qualitative and quantitative approaches are accepted, including in studies in which they serve complementary purposes. However, it is also true that this acceptance remains grudging in some circles and that hard-nosed positivists and 'purely' qualitative researchers do little more than tolerate the presence of the other. Against this background complemented by those peopling some middle ground, we can ask how those who specialise in both Mathematics and Education can add a positive voice. Firstly, it is of significance that the term is 'Mathematics' not 'Statistics', although some may legitimately claim both titles. It is significant because for much of the methodological world the terms are regarded synonymously.

There are three aspects within which I believe we can contribute conceptually.Firstly, to continue to refute the erroneous assumption that the use of mathematical representation is necessarily associated with positivism. The fundamental tenets of positivism are the separation of fact and value and a belief in the universality of 'laws' irrespective of context. That these lead to and support the design of experiments and thence the use of statistics does not mean that the latter implies the former. Such an assumption represents one of the most fundamental mathematical mistakes – the confusion between necessary and sufficient conditions. Statistical representation and calculation can provide productive illumination within many contexts. But this is essentially a defensive response and my argument here is that we should be using our Mathematics background in a positive sense – to occupy the high ground as it were. To do this we can invoke one of the 'favourite sons' of contemporary social science viz deconstruction. Just as the post-structural view claims the validity of deconstructing and re-constructing the meaning of text, and rejects the concept of single imposed meanings, so we can invoke the commensurable 'right' to deconstruct the meaning others may traditionally have imputed to the use of statistics in research, and to reconstruct it, for example, in terms of a descriptive illuminating representation of case study data. Put another way, we are importing mathematics as a form of communication into the discourse of research reporting, and claiming no more nor less than that the accepted norms of discourse analysis apply.

Secondly, we can contribute a balancing dimension to the important principle that value free observations do not exist. Typically presented as an argument that every quantitative measure involves a qualitative aspect (i.e. the set of values or the theory that prompted the decision to obtain that particular measure), we can likewise argue that no purely qualitative research is possible. This has been a fond claim of some of the more vehement opponents of quantitative measurement. Quite simply, every qualitative decision involves a quantitative element. The decision to ask this person rather than that one for an interview, to include this question but not that one on an interview schedule etc. means that more 'units of worth' have been attached to some alternatives than to others. Behind every qualitative design there lies (at least) one ordinal scale. A purely qualitative study does not exist either.

Thirdly, our Mathematics should equip us to contribute to debates that invoke arguments claiming support from broad mathematical theories. A contemporary example would involve Chaos Theory with appeal to sources such as Gleick (1987). An argument I have seen in various forms runs along lines that typically appeal to some version of the "butterfly effect". Essentially, it argues that because chaotic modes have been shown to exist in many complex non-linear systems, and because social systems such as educational organisations are examples of such systems, we can expect unpredictable outcomes (chaotic regimes) no matter what programs we put in place. This latter inference is derived from the property that for chaotic regimes different outcome patterns are obtained from initial conditions that vary even minutely. My objection in spirit is that the view is defeatist and pessimistic, and on the basis of reason that it is erroneously incomplete. When confronted by such reasoning, there are two responses that can be given. Firstly, that chaotic behaviour occurs generally across a very small volume of parameter space – that is the vast majority of behaviour modes will be non-chaotic anyway. Secondly, that for modes that do exhibit chaotic behaviour the settling time (time to become independent of initial conditions) is often significantly long. For interest I ran a model of a small social system, and the time taken for chaos to set in was what we might agree could be regarded as substantial – about the same time as between the present day and the battle of Waterloo! Given the normal timescales associated with curricula, schools, universities, and other learning centres it is safe to say that initial conditions will usually retain much greater influence on outcomes over the relevant time-period than the potential of chaos. What we try to achieve does matter! Our child of the future will not thank us for giving up on the grounds that chaos is likely to emerge anyway.

Finally, in a methodological vein it is worth noting that Mathematics Education is unique in that its theory and practice involves separately, and in various combinations logico-deductive knowledge, empirical scientific knowledge, and knowledge derived from the naturalistic (Lincoln & Guba, 1990) and critical (Gibson, 1986) paradigms. That methodological issues continue to arise is not surprising, noting that even the first two of these (often combined in both professional and popular circles) are not necessarily viewed as close companions within the scholarly community; for example as noted by Snow (1948) in a celebrated essay on G.H. Hardy. We should continue to expect to be exercised by methodological challenges and in finding how to inject our perspective into debate.

Where? and Who? Questions

One of the most frustrating of all searches is for points of influence and impact? Where and on whom should we concentrate our efforts? Where and to whom should we present our findings? Where can we find forums and tools of communication to reach and convince our necessary audiences? Who are these audiences and whose arguments carry the greatest weight?

These examples include at least two meanings of 'where' – political content and physical location. The latter is fairly obvious – as an example of the former consider the use of the terms such as *accountability* that are increasingly part of the education agenda. A word such as *accountability* can be construed as, following Wolf (1996):

(i) being able to *explain* actions; or
(ii) being responsible *for* some actions; or
(iii) being responsible *to* someone for actions taken.

These interpretations have substantially different meanings in practice where for example (i) allows considerable teacher autonomy while (iii) could mean the withholding of funds unless prescribed standards and methods (as specified by major stakeholders) are followed.

So in addressing questions of *where?* and *to whom?* the matter of the various "interests" served by concepts, procedures, and individuals is brought into focus.

The question of "interests" as applied in education generally has been associated with the 'critical theory' movement from which it has drawn its conceptual basis (Habermas, 1971; Gibson, 1986; Carr and Kemmis, 1986). Three levels of interest have been articulated, viz technical, practical, and emancipatory, and much has been written concerning these in the general teacher education literature, see for example van Manen

(1977) and particularly Zeichner and his associates (Zeichner and Liston, 1987; Zeichner, 1993). For completeness a brief summary of the characteristics of these interest positions follows.

Technical interests refer to the interest in gaining knowledge for the purpose of efficient and effective application in controlling the environment defined in a broad sense. This may be taken to include the attainment of prescribed educational objectives requiring technical skill, and mastery approaches to learning and assessment provide an exemplar for the achievement of technical interests in mathematics. Technical interests are not bad in themselves, however they do not represent the only kind of knowledge to be sought.

Practical interests refer to a conception of action that involves explicating and clarifying assumptions behind alternative actions and evaluating the ultimate consequences of the actions, such that actions and decisions are linked to value positions and those who are actors in the system must consider the worth of the various alternatives.

This type of knowledge is concerned with interpretive understanding. However, the subjective meanings embedded in aspects of this knowledge are controlled (limited) by the context in which it is enacted, and hence govern the extent of what can be achieved. Reflection plays a significant role in developing the scope of *practical interests, which* might encompass, for example, acceptance of a range of teaching approaches and assessment types as necessary to meet and evaluate varied aims, and types of mathematical activity.

Emancipatory interests refer to issues of justice, equity, and fulfilment, and can only be served by a 'critical approach' that identifies the restrictions referred to above and reveals how they may be eliminated. Thus they offer an awareness of how aims, purposes and possibilities have been repressed and distorted, and what actions are required to eliminate sources of inadequacy or frustration.

It is the distortions that offend this latter viewpoint not the pursuit of other interests as such. For example, technical interests may facilitate emancipation through the provision of mathematical power to learners, but they may also disempower through culturally inappropriate methods of teaching or assessing and thence accrediting competence.

In turning attention to Where? And Who? questions it is useful to invoke these conceptions of *interests* as a lens through which to view the content of Mathematics Education. Returning to the concept of *accountability* we consider how it might be interpreted within an Education system. If we define the term as meaning *being able to explain actions* (i.e. account for) we give freedom for teachers and schools to argue for or defend a variety of teaching and assessment practices based on corresponding value positions – practical interests at least are provided for. If we define the term as *being responsible for some action* we again locate the power and responsibility with those who design the learning and the assessment. Decisions made must be defensible in terms of the context of operations. If however the term is defined to mean being *responsible to someone (or some organization)*, then there is a major shift in the location of power which might involve a requirement to carry out a particular educational program with non-compliance punishable by withdrawal of funding. Interests served in this situation are likely to be narrowly technical, and those who value practical or emancipatory interests are similarly outraged by this position, an outrage which is often compounded by their exclusion from the design and rationale of curricular and assessment procedures. The former's outrage is essentially intellectual, concerned for the quality of mathematics mandated by the procedures; the latter's outrage extends to encompass the political – concern for both students and educational professionals, at the narrowly technical expertise they are offered, and concern that educational decisions have been usurped by ideological expediency. National testing and benchmarking systems are sources for such concerns.

The point at issue is that of involvement. At the outset terms like *accountability* tend to be used as buzzwords in as yet uncrystallised forms. Emancipatory interests would demand that the profession become involved at the outset, while there may still be time to influence the ultimate decision, and to fight where necessary to overthrow imposed structures and definitions deemed educationally or morally unsound or restrictive.

It is possible to go on to identify conflicting interests in almost every area of Mathematics Education practice. The question is what this does for the advancement of knowledge and process, for awareness and critique at one level can serve to harden and re-ify opposition and defences at another, or can remain simply as critique. One possible path to progress is to adopt a *dialectical strategy*, that is to specify potential conflicts of interest and subject them to informed rational debate, rather than polarize and entrench opposing viewpoints through verbal attack or to strive for an uneasy but superficial peace. To question rather than condemn is also consistent with the Habermasian approach exemplified in his promotion of the Ideal Speech Situation (Habermas, 1971; Gibson, 1986).

The ideal speech situation (ISS) requires that each individual communication possess four qualities. It should be

(a) comprehensible – e.g. made in a shared language
(b) true, i.e. matching what we perceive as reality
(c) correct, i.e. legitimate within the context of the topic
(d) sincere

Furthermore, the ISS requires that all speakers (or communicators) have equal rights to dispute, assert and question and, by inference, have equal access to relevant knowledge. Put differently, this requires that an ISS be free from domination and, given this condition and genuine goodwill, progress can be pursued by rational argument.

It is not however difficult to identify impediments to this ideal in our debates on issues in Mathematics Education, e.g. unequal 'rights of speech' afforded to political voices versus educational voices, administrators versus teachers, academic mathematicians versus professional educators, parent demands versus teacher ideals, competency advocates versus wider mathematical adherents. Witness for example the difficulty MERGA experienced in attempting to have its voice heard by DEETYA.

How might such an approach work? A simple beginning would involve selecting issues of significance and for each posing questions that direct debate to the intellectual content and power relations represented by identified alternative interests made public. The following examples illustrate the dialectic properties of this approach.

Interests of teachers in developing understanding	vs	Interests of students in achieving grades
Interests of administrators in placating parents	vs	Interests of teachers in using innovative assessment
Interests of schools in meeting numeracy benchmarks	vs	Interests of weaker students abandoned to enable others
to		reach that level
Interests of subject heads in controlling curriculum	vs	Interests of teachers in developing best practice
Interests of technocrats in proliferating technology	vs	Interests of professionals in requiring quality learning through technology
Interests of universities in circumscribing school	vs	Interests of schools in increasing professional

mathematics		autonomy
Interests of Testing Services in selling instruments	vs	Interests of teachers in designing assessment
Interests of the 'State' in competency measures	vs	Interests of the school in quality measures

And we might add a third column – the interests serving the question asked by our ghost child!

Such a listing is not intended to imply a "good" versus "bad" characterisation. *The purpose in establishing a dialectic is to create an agenda and a forum through which interests may be disclosed and addressed that are often present but not made public.* While there is no assurance that this will always work, public declarations of position and the relentless exposure of assumptions, enhance the possibility of progress and render a little less likely the use of vicarious means to avoid confronting issues and the use of managerial methods to overthrow educational goals.

A question of scale

So the six honest serving men have had a say. It is clear that they are versatile and able to overlap their functions. What? questions can be readily re-phrased as Why? or How? questions and so on. What is also clear is that their questions permeate all boundaries. The downside of this is that they do not in themselves provide measures of relative importance, scope, or urgency. Another way of approaching issues is to estimate the extent and type of their impact. This was attempted by Kaput and Thompson (1994) in their use of nautical metaphors to describe the perceived profundity of the impact of aspects of computer technology on mathematics learning. Borrowing their terminology with suitable adaptation we obtain the following classification:

Surface wave:	represents procedures and impacts at the level of the individual classroom, school, or institution.
Swell:	larger scale and more pervasive so there is impact at the local system level.
Tidal wave:	generated beyond local boundaries and frames of reference and requiring time-scales with larger orders of magnitude.
Sea level change:	fundamental reshaping, analogous to a change in sea level produced by global warming.

Using this broad classification we can begin to assign issues to the various levels – acknowledging that clearly a substantial element of subjective judgment is involved. Looking across the large range of studies represented by the ICME Short Communications it appears that the vast majority are at the level of *surface waves*. Examples might include variations of classroom organisation, studies on student learning, the development of contextualized assessment materials such as school-based projects, and the use of performance data alternatives such as innovative writing tasks, interviews, and various kinds of application tasks. Also included would be most technology based learning initiatives.

At the *swell* level we note moves to augment formal certificate examinations by a greater range of alternative performance measures including increased use of teacher judgments. Some noticeable activity at national levels is occurring in countries such as African states that is related to opening mathematics to groups previously unable to participate. In some Eastern European countries a reverse effect has been noted, in that talented youth are being targeted to mitigate potential fall-out from a loss of direction and increasing vagueness and uncertainty that is a legacy of the major political changes of the past decade. The impact of National Statements and Testing Programs would be appropriately included here.

At the *tidal wave* level we look for more pervasive change, identified beyond the boundary of a local system and represented and sustained by strong broadly based influences. Although not necessarily legislated into practice, such influences can gain their strength from internationally located movements that impact through professional exchange. Contemporary examples would be the transforming action of a new epistemological stance such as constructivism, the impact of Vygotskian psychology on collaborative learning approaches, and the changes wrought by some countries in response to outcomes of international studies of mathematics achievement. Perhaps also the movement to link mathematics with elements of local culture and real world applications, that has developed an increasing international presence. In a previous generation various versions of the "New Mathematics" movement would fit this classification as would the influence of Piagetian theory and practice.

Although tidal influences are profound, there may still be regions that remain isolated from their impact and for a *sea-level change* we envision uni-directional forces of massive impact and irresistible momentum. As a past example we might consider the development of communications, including the series of ICME conferences and the establishment of international journals in Mathematics Education that have changed forever the relationship between individual members of our international academic community; although whether there has been commensurable impact on practice could be contended. It would be a very wise or very foolish individual who felt confident to predict definitively on such matters so I will merely suggest three that seem to be potential candidates.

They are respectively the continuing development of mathematical software and associated technology, the communication properties and potential of the Internet, and globalisation as represented by an internationalisation or notions of competence and standards as a consequence of a developing international trade in qualifications and courses.

The nautical metaphor is introduced to address the problem of structure. The issues we consider, the research we undertake, and the reports we write tend to be important but undifferentiated, apart from classifications by topic or interest group that may be used (indeed productively) to organise presentations into cognate groupings for presentations at conferences such as this, or for publication in monographs or special journal issues. This method of organisation seems to resemble J.J. Thomson's plum pudding model of the atom with issues (clusters of electrons!) scattered like currants and raisins in an amorphous mass labelled Mathematics Education.

The nautical metaphor (primitive though it is) is intended to facilitate a classification closer to the Rutherford – Bohr model by separating issues and themes into 'energy levels' on the basis of their perceived location, pervasiveness, and ultimate influence. This is a crude device but may provide one way of structuring research content into 'family groups' that can then, if desired, be examined using other sets of dimensions such as 'interests served' or cognate topic grouping.

Conclusion

One of the frameworks we have found productive in current research is the concept of a community of practice. The mathematics fraternity has, over a period of centuries established norms and customs through which to evaluate and refine the standing of new mathematical claims- a socially constructed community of practice. Classrooms organised along community of practice guidelines aim to develop a similar environment for the exploration, testing, and refinement of ideas and conjectures, leading to authenticated mathematical knowledge (Goos, Galbraith, & Renshaw, 1998). Yet there is a potential irony in the dedicated application of constructivist principles to learning environments, in that while there is encouragement to construct, interpret, and re-construct understanding there is a noted exception." You (the student) are encouraged to challenge and reconstruct all aspects of classroom activities except one- the overall constructivist approach through which I am teaching you". Such is an example of the epistemological dilemmas that need to be addressed.

When we add (capital E) Education to (capital M) Mathematics we change the norms of our total professional activity in a radical way-particularly when embracing contemporary principles such as post-modern theory. The consequences I suspect are that the Mathematics Education community is plunged into an exercise in constructivism far more profound than that occurring in any classroom. Our community does not yet have an agreed knowledge base or set of procedural norms to which to appeal-for that is part of the construction in progress. To use an analogy from the history of mathematics, that I have applied elsewhere to issues in assessment, we can think of ourselves as growing through our Babylonian and Egyptian periods in which imperatives of pragmatism and urgency, arising through our responsibilities towards the human subjects involved in all our work, have seen us engineer and develop methods tailor made for the urgency of the moment and the location. To progress according to the analogy into and beyond the Greek period means attempting to set our practices within a consistent theoretical framework-mathematics would seek such order, post-modernism might argue it is a false goal.

In any case there is the need to ask searching questions on account both of the current influences in our field, and on behalf of our child of the future whose destiny we are helping to shape. In this address/paper I have suggested just two possible ways to interrogate our activities. I do think there is a need to look for structures and to estimate the potential future significance of topics and issues that at present are distinguished only by their content, and the nautical model is a beginning attempt to address that need. Ultimately the way our field develops depends upon the ongoing synthesis that results from the giant exercise in social constructivism that our community is engaged in. Within this activity two extreme responses threaten our collective progress. One is withdrawal from debate on the grounds of irreconcilable differences, the other is comfortable living within a closed community of like minds.

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