Research As …
Explorations of Theories and Methodologies of Research

John Gough
Deakin University
Faculty of Arts & Education
(with co-author contributions from some others)
A draft eBook on the topic of Educational Research, for teachers, student-teachers, educators, and researchers
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Preface

This book is built on my decades of professional activity in teacher education. Since 1975, in several different tertiary institutions, in Australia and Papua New Guinea, I have trained pre-service teachers, and instructed graduate teachers in many subject areas. Beginning in Secondary mathematics education, and then Primary mathematics education, I later branched out into Remedial education across the curriculum, Literacy education, assessment across the curriculum, giftedness, Logo computer programming, the uses of children’s literature across the curriculum, and other areas that interested me.

In 1993 I began attending the Symposium on Contemporary Approaches to Research in Mathematics, Science, Health and Environmental Education, at Deakin University, organised by the then School of Mathematics, Science, Health and Environmental Education in the Faculty of Education. Amazed by the diversity of research methodologies and fields of research, I wondered if I was capable of any kind of research. Then I began to wonder if any of the things I was already doing as part of my on-going professional activity (much of it teaching, supported by wide reading, critical analysis, and writing instructional materials) constituted research. Slowly I came to conclusion that, in my own ways, without ever competing for research funds, or taking time away from my teaching to go “into the field” and “collect research data” (the dominant paradigm for other researchers) I was actually a researcher. Many of the articles I wrote and published in professional (not research) journals were in fact reports on my own researching.

This led me to dare to offer my own papers at some of the continuing the Symposia on Contemporary Approaches to Research in Mathematics, Science, Health and Environmental Education. Some of the major “chapters” in this book are versions of these Symposia papers.

Other materials compiled here reflect other aspects of my research-like professional activity.

If any one “chapter”, or page, or idea is helpful to anyone else, I will regard the compiling of this book as having been worthwhile.
Turning School Investigations into Valuable Research

Graham Ferres (Monash University—Frankston Campus)
John Gough (Deakin University—Burwood Campus)

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Abstract

Many school teachers at Primary and Secondary levels are involved in professional development, curriculum innovation and similar tasks related to teaching, reporting and accountability which seem remote from ideas of 'educational research'. However by exploring the nature of Action Research and other research models it is possible to suggest ways that teachers can reflect more critically and constructively on professional activities to which they are unavoidably committed. A typical 'topic for informal investigation' is used as the basis for discussing such possibilities. Particular attention is focussed on clarifying the teaching and learning being attempted, to ensure that clear and informative data can be gathered and analysed.

How can project investigations at school, or about school, be turned into solid research? Increasingly teachers are asked to implement new ideas, new techniques of teaching, new curricula, and new methods of reporting. Teachers are also professionally responsible, accountable to their students, the parents of their students, to colleagues, and to their employers. They have little choice about introducing changes in their teaching. As a result of developments in technology, for example, teachers must bow to the pressures for curriculum changes which exist in the whole community. Out in the real world, fountain pens give way to ballpoints, and handwriting is increasingly challenged by the need to develop keyboard-based communication skills, not to mention widespread community acceptance of calculators, computer-based cash registers, and computers. How can teachers try to ensure that educational changes in their schools are being implemented as effectively as possible? Such questions need careful investigation and reporting – research.

Action research is critical practice

First, at the simplest level we can try to provide an account of what we are doing as clearly as possible. The result is a descriptive case study: this is what I did, this is why I did it, this is what I used, and this is what I noticed happening. Such a report might be extended by including an account of what I used to do, and why I thought it might be useful to change from this. With a little polishing this kind of simple anecdotal description can be turned into a more developed form of action research. What kind of research is this? How does it relate to ordinary events that occur in ordinary schools?

Action research has been rather grandiosely defined as 'research undertaken by practitioners in order that they may attempt to solve their local, practical problems by using the methods of science' (Ary, Jacobs and Razavieh, 1972, p 36). In this definition, the relevance of the 'methods of science' (with its emphasis on scientific objectivity and its formal stages of 'scientific method': defining a problem, stating a hypothesis, deducing consequences of the hypothesis, collecting and analysing data generated in an attempt to test the hypothesis, evaluating the hypothesis in the light of the test: Ary et al. p 37) may
be questioned. One of the pioneers of action research, S.M. Corey, was less concerned with science and emphasized that research about schools (or comparable organizations) should be carried out in schools, by those who may have to carry out any changes that may result from the research (Corey 1954 p 8, cited in Ary at al. p 44).

In fact action research was first proposed by the social psychologist Kurt Lewin (for example, 1946) as a process of cyclic study, diagnosis and therapeutic intervention which resembles a doctor's attempt to help a patient through successive cyclic stages of first ideas, fact finding, planning, therapeutic action steps, monitoring, evaluating, replanning, and so on (Lewin's cycle is described in Burns 1990 p 253). In Australia, action research has been recommended enthusiastically by Kemmis and McTaggart who defined it as:

- a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the productivity, rationality and justice of their social or educational practices, as well as the understanding of these practices, and the situations in which these practices are carried out (1988 pp 5–6).

Doesn't this sound like the kind of thing teachers do all the time as they sit in staffrooms, talking shop, trying to sort out what they are doing, and how to do it better? The only remaining steps, apart from talking about it, is to document the institutional setting, the issues, and the talk as clearly as possible. (See also McTaggart 1991, and Kemmis 1994.)

Unlike the intended objectivity of a scientist, psychologist or doctor dispassionately observing and evaluating events in the laboratory or processes in the patient, the teachers and educational professionals who carry out action research are themselves participants in the events they are attempting to deal with, identifying 'strategies of planned action which are implemented, and then systematically submitted to observation, reflection and change ... [and] integrally involved in all of these activities (Kemmis and Grundy 1981, cited in Burns 1990 p 252).

Not only is objectivity difficult, in action research, so is any attempt to control all possible variables in order to gain scientific experimental rigour, and the ability to identify significant factors with certainty. Teachers use 'research methods to study classroom problems', a teacher 'conducts the study or has an important role in the research process', and, 'because the focus is on a solution to a local problem... rigorous research control is not essential' (McMillan and Schumacher 1993 p 21). Indeed a control group of school children which is given no treatment at all is obviously out of the question in an institution where professionals are paid to deliver some kind of observable service to their clients.

Given these definitions and descriptions, action research may be best thought of as normal professional work relating to a particular problem or research question, with a more focussed research-slant, actively probing definitions and assumptions, raising questions, examining different kinds of evidence, and implementing different kinds of practice in an attempt to find answers to the questions, and eventually achieve a solution to the initial problem. Equally action research can be used to investigate or critically describe the possibly unchanging (for the moment) status quo in a classroom or school, as Kemmis and McTaggart imply when they speak of action research investigating existing practices and situations.
Kemmis and McTaggart's 'Planner' (1988) identifies four interacting major stages in action research: reconaissance, planning, enacting and observing, and reflecting. Following Lewin, they point out that action research is participatory, and proceeds in systematic but flexible cycles, starting small, investigating small changes, using collaborative theorising and critical reflection. They suggest several guiding questions that can link the stages, at the same time distinguishing three overlapping domains within which the research falls: language and discourse, activities and practice, and social relationships and forms of organisation (Kemmis 1994).

Ferres offers the following questions as a guide for teachers (or other participant researchers) considering related background (reconnaissance) studies, and their own experience and conclusions (reflecting):

- Which known research findings match our understandings, our experiences, and our observations?
- How might we organise the key ideas in our work?
- What interpretations and conclusions from our own experiences might we add to this other research we have collected?

Both of these questions relate directly to forming

- strategies and environments for effective learning (by the participants, and other teachers)
- plans for working in professional development groups (1996).

The goal of action research is quite simply the goal of education – to improve educational practice, or ensure it is as good as possible. Action researchers are participants, and cannot pretend to be scrupulously objective. But they can be as honest as possible about their biases, or their guiding assumptions. They can be scrupulous in their efforts to define and discuss with clarity and precision. They can also invite the contributions of outside observers and analysts, and place their best efforts open to the frank scrutiny of a wider public.

**Linking action research with experimental approaches**

With just a little planning we can even turn project investigations at school, or about school into a kind of **pilot-study research project**, possibly even with an experimental or quasi-experimental basis. The following comments may help ordinary teachers or students achieve any one of these three possibilities, with little further effort beyond ordinary day-to-day work activities. The pay-off is that teachers will then be in a far stronger position to discuss their work, to take real charge of their own curriculum, and to give a professional account of their working activities. Kemmis notes that action research 'creates an immediate sense of responsibility for the improvement of practice' (1994).

Frequently students, at secondary levels through to undergraduate tertiary levels, and even post-graduate levels, attempt to carry out a piece of work which tries to answer some question about their own student learning, or the learning of themselves and a group of peers, or to evaluate a piece of curriculum, or report on the stages they went through attempting to solve some mathematics or other problem. For school students this may arise via self-reporting, journal-keeping, and typical VCE CAT investigations where a folio, logbook, diary or journal is kept of successive drafts of student work, perhaps including the student's reflections on these successive drafts. For tertiary level students
this kind of work is typical of university assessment tasks, research projects, and minor and major thesis research.

For teachers in schools who are not directly involved in tertiary study or research, this kind of tentative problem solving work arises during personal and collaborative staff professional development projects. Since the central support mechanisms of the Education Departments and government agencies around Australia were dismantled or disabled or demolished, because of staff cuts, funding cuts, and magic words such as 'rationalising', 'down-sizing', 'devolution' and 'school-based curriculum', teachers have been forced to pull themselves up by their own bootstraps. Once upon a time there were Inspectors, and Subject Specialist Consultants, and Curriculum and Research Branch experts, and Task Groups. Now there is chaotic anarchic free-for-all. In such a work climate, clearly teachers need to keep as clear a head on their shoulders as possible. Maintaining good notes and records of the work they are doing, of their questions and concerns, is an invaluable way of doing this, and forms the basis for any eventual 'research report'.

**Implementing curriculum change – a typical example**

Consider a hypothetical example of a curriculum development project at school such as a new teaching activity about to be introduced. For the purposes of this discussion it will be given a plausible, and intriguing formal title. But exactly the same project could be initiated at a school by a keen teacher with no clear sense of a project being present at all, simply, new teaching materials and activities starting to be used in classrooms:

'Using Computer Software to Enhance Learning in the Space Strand of the Mathematics Curriculum and Standards Framework'.

Indeed it is easy to imagine a teacher, or team of teachers, attempting to use a new collection of computers and some newly acquired software, wondering just what might come out of this, and feeling a little uncertain about what they will do, and what will happen. Will they be able to monitor what they are doing? How would any of this apply to the rather intimidating, but mandatory(?) CSF? Alternatively, rather than focussing on the CSF strand of Space, we might consider possible uses of computer technology and software in the strands of Number, Measurement, Chance and Data, and so on. Related topics might arise through questions about the possible role of calculators, or the new-fangled Internet, or other new technologies, or even the simple introduction of a new textbook, or series of reading materials, or a new method for teaching spelling, or a new handwriting style.

The focus of the hypothetical example is clearly stated in its title: using computers to help children learn to think and work better with spatial aspects of the current mathematics curriculum. In fact, merely giving a title to an otherwise ordinary school teaching activity, such as introducing some new materials or beginning with a new textbook, helps to focus on the research-like problem solving nature of such ordinary teaching. I am going to try out this: I wonder how it will work? Next, we might want to be more specific, and pin down exactly who we are working with. Will we concentrate on a small group, or a whole class, or several classes, or year levels? Will the school setting be an urban Primary school, a rural Primary school? We might even work with children outside of an ordinary school setting, such as an after-school program, a holiday enrichment program, or individual 'coaching'? Will the students in the project be volunteers, nominees, or compulsorily drafted?
'Experiments' in education

How will we set about our work? Will we build some kind of computer and technology use into an otherwise ordinary curriculum, and then simply describe what happens? Will we attempt to compare one group of students who have an ordinary curriculum with a different group who have a computer-based curriculum? Here we are really considering aspects of what is known as experimental design, or perhaps quasi-experimental if formal experimental controls and technical restrictions of the strict scientific approach are considered to be impracticable or not feasible for some other reason, such as the ethical limitations on the way we can experiment in the curriculum and its delivery with one group, while deliberately restricting the curriculum input and teacher-support provided for another (controlled) group. (For example, Campbell and Stanley 1963; and McMillan and Schumacher 1993 chapter 9.)

What do we mean by 'experimental' and 'quasi-experimental'? Some research purists claim that the term 'experimental' should only used when the researcher randomly allocates the so called 'experimental subjects' to different experimental or trial groups. But the researchers or teachers may actually have no say over which student is in which class. Nor would we be able to consider the possible effects of interaction between friends if group allocation randomly splits up the normal student-selected social groupings, and the disorientation of broken friendship bonds might effect our study. The design of an 'experiment' also requires a so called 'control' group for comparison purposes. In such a 'control' group nothing special happens, perhaps other than routine curriculum and classroom activities, except for initial and final experimental 'testing' of some sort.

As an example of a very neat experimental design, consider Peter Sullivan's miniature study (Sullivan 1983; Gough 1984). Forty-four students who had completed mathematics up to Grade 10 in Papua New Guinea were enrolling in a pre-employment technical course. Part of this course involved some basic arithmetic and mathematics which might have been assumed to have been covered in earlier school years. But previous experience showed that whenever such students were given a pre-test of basic skills they appeared to need considerable extra remediation in order to be brought up to a satisfactory standard. Sullivan administered the pre-test, as usual. But then he randomly divided the students into four equal-sized groups, in an attempt to explore the usefulness or otherwise of the remediation classes that almost all of them seemed to need, according to the rather dismal results of the pre-test.

The first group was taught the standard Basic skills course by a mathematics lecturer. The second group was given an equivalent arithmetic course taught by a trade lecturer. The third group had their errors on the pre-test carefully explained, but otherwise received no further assistance. The fourth group (the control) had their pre-test papers returned, but undertook no kind of mathematics teaching or remediation. All groups were told they were going to be given a second version of the pre-test, and they were told that the results of this post-test would count towards their pre-employment course. After the post-test, careful statistical tests investigated possible differences between the students.

In fact there was a small uniform overall improvement between pre- and post-test for all groups, but there were no significant differences between the four groups. This improvement was also found to hold when a second post-test was given eight weeks later.
to measure longer-term skill retention. Having carefully controlled the relevant variables (the different treatments each group received, or did not receive, combined with random allocation to a group) it was possible to see that the specially designed Basic skills course was no more effective as remediation than doing nothing at all, except testing once, and then testing again, knowing that the second time would count. Amazing, and neat.

Research purists want scientific rigour in their research, and the control of variables. But almost always scientific rigour has no place in a school, or is too technically restrictive. How can we attempt to control for such variables as the time of day when a lesson occurs (some research suggests students learn mathematics or any school subject better in the early morning, and better still after some minutes of aerobic exercise, rather than after lunch) when the school timetable is not able to be altered by the researchers? What about the variables involved in different teachers taking different classes? Even if we limit our study so that only one teacher teaches all the experimental groups, we are unable to control for the different prior influences of previous teachers, or the impact of other teachers at other times during a school day, or even the effect of the students' parents outside of school hours. Of course if we restrict our research to one-teacher schools, to increase our control over teacher-related experimental variables, we would then be unable to generalise any results, experimentally established for one-teacher schools, and draw conclusions that might apply to schools with more than one teacher. Damned if we do, and damned if we don't.

Moreover the do-nothing requirements of a control group may not be ethically justified when working with humans. Is it fair, for example, to allow one class in a school to have eight-hour-a-day access to one computer for each student, when the class next-door has no computer at all, or only one hour-per-day access to one computer for the whole class? In such cases, we may relax the purists' standards and perform semi-scientific or quasi-experimental work. This need for a more humanely relaxed, indeed professionally responsible, approach to experimentation and research, a more realistically oriented experimental response to the human needs of teaching and learning in ordinary classrooms, led originally to the development of the concept of 'action research'.

The absolute control of scientific experiments that can be exercised over, say, laboratory rats, has nothing or very little to do with the naturalistic uncontrolled and extremely complex setting of a school, itself set within a much larger and naturally varying social context. No wonder quasi-experimental and action research, or simply descriptive case studies have so much value for the important goal of improving school practice.

'Learning' and the need to measure change
Once we have the broad design settled, how can we begin to experiment, measure, and accumulate research data? In a teaching climate where the profession as a whole is opposed to 'testing' of students, softer options are often suggested. However, observation and interview alone, though these may seem to be avoiding the bogeyman of testing, can only describe what appears to be happening during the period being studied. They are unable to measure change in behaviour, or even indicate whether or not any change is occurring. But learning is precisely a matter of 'change'. That is, such a test-free approach to the study offers neither quantitative (measurable) nor qualitative (describable) data on children's 'learning' about the ways they are actually changing. It only reports on some of
the children's activities and the associated curriculum development that led to those activities.

The only way we can try to say anything about whether or not children (or students, generally) have learned is by being able to identify the way they have changed, and the extent that they have changed. How can we know when change occurs? This is only possible if we have information about the way the children were at the beginning, and we then compare this with the way they now are at the end. We actually need to be able to do a simple kind of subtraction:

- What the children know at the end
= What the children know at the beginning
- What they have learned in between

If all we are dealing with is description, rather than any kind of test-like measurement or other data, then we need a clear, detailed description of what the children know at the start, and, after lots of description of what is happening during the period being studied, we then need a clear, detailed description of the way the children have ended up. By careful comparison between the beginning-description and the end-description, we can identify those new kinds of behaviour and changes in understanding that have (we presume, and hope) resulted from the time and effort spent during the period of study. (It is always possible that the children may have changed for reasons that have nothing to do with our attempts to 'teach' or facilitate learning.) This comparison is the equivalent of the arithmetic process of subtraction (indeed, subtraction depends on underlying comparison, and is a process of reporting on the quantified results of comparing quantities). These 'new' things are evidence of the change in the individual which simply is 'learning'.

If, as well as descriptions, we have more quantifiable evidence, such as performance on work sheets, responses to attitude questionnaires and scales, and even 'tests' of some sort, then the comparisons we need to make, to establish whether or not there have been changes, and if so, to establish how big the changes might have been, are easier to make, and more objective, although naturally constrained within the limitations that attend any reliance on pencil-and-paper work, right or wrong answers, time-limits, and so on. The human detail we can obtain in large amounts by interview, observation and subjective description (possibly guided by checklists and pro forma observation records), is balanced against the directness and hardness of other kinds of data that can be obtained from written and computer records of student work.

Is this learning 'enhanced' or 'ordinary' learning?

However, the key question in this sample topic 'Has learning been enhanced?', or even the related question 'Has learning occurred?', can not be easily answered by such a study without further careful thought.

What does 'enhancing' mean? Surely it means that some situation has been improved beyond what would have otherwise been possible. Attempting to investigate 'enhancement' (of spatial thinking, or some other aspect of mathematics, or other curriculum area) through the use of computers would require some consideration of alternatives to any use of computer technology as a possible way of producing technologically 'unenhanced' learning. This might, in the case of spatial thinking for example, involve pencil-and-paper activities, scissors-and-cardboard constructions, use of
birds-eye-view and plan diagrams and blocks or other building materials, map-making and map-interpreting, and other non-computer-based spatial thinking activities. The level of learning outcomes from these alternative activities could then be compared with the outcomes for the study's computer-based activities.

If the students who did computer-based work achieved higher levels in their development of spatial thinking, then the computer-based curriculum could be said to have 'enhanced' what might otherwise have taken place without the computers. Alternatively the students using computers might have achieved development of spatial thinking which was only comparable to, or even inferior to the levels observed in students who did non-computer-based spatial thinking activities. In this latter case the computer-based curriculum might be considered to have not 'enhanced' at all, but might even have resulted in a lesser level of development. It is easy to imagine that students who are using computers, many for the first time in school, may be so enthusiastic about the computers themselves that the technology actually distracts them from what the technology is supposed to be teaching them. By contrast, sheer familiarity with ordinary materials such as cardboard, glue and scissors, may allow students to focus more constructively on the ideas being represented through these everyday materials.

As has been discussed briefly already, the broader question – 'Has learning occurred, enhanced or otherwise?' – can only be asked by making benchmark comparisons between some kind of entry-level evaluation of spatial thinking ability (or whatever the subject being researched) and that ability or achievement at the end of the period of study. The learning evaluation or measurement equation is simple: Post-'test' minus pre-'test' equals 'learning'. Formal pre-tests and post-tests could be carried out using the ACER Space Test Unit 1 (MAPS Mathematics Profile Series 1978), or selected geometry and spatial thinking questions from Schleiger's Diagnostic Mathematical Tasks, or by taking appropriate examples from the Mathematics Curriculum Profile (Curriculum Corporation) or even the points of the C&SF Space Strand itself, or other curriculum resources such as items from the current LAPS (Learning Assessment Project) tests (some of which are known to indicate at least a low-level of spatial thinking), or even making an informal school-developed test.

An alternative informal approach to entry- and exit-assessment can be attempted by combinations of questionnaire, student journal, or structured interview before the study and after it. For example, students (and teachers) can be asked to keep a journal in which they record their thoughts and experiences and questions about some topic, starting with simple instructions to 'Write about what you know about different kinds of shapes such as squares, and triangles and circles', and further instructions to write about subsequent lessons on related topics, finishing with "What have you found out now about two-dimensional objects?".

Of course the scope of research needed to attempt to deal with these all of these questions considerably exceeds post-graduate course work requirements, for example. It might fruitfully form the basis of a complete PhD, and could conceivably even go far beyond the scope of a PhD as a long-term subject for investigation. Some researchers could build a substantial professional academic career out of the attempt to explore such a topic. Any research study that runs for a part only of a school year, with only a class or two being studied, even if the data collection was adjusted so that it could really come to grips with the stated research question(s), in the time allowed, would not be able to do full justice to
the topic. Instead such a naturally restricted project could provide a much simpler pilot study or ‘dry-run’ for possible later extended research. This kind of small-scale action research prototype is capable of yielding very good work. Similarly, as a piece of school-level curriculum development, and accountable professional development, this kind of action research can meet its target goal – to provide documentable feedback about teaching practice, to inform future practice and to guide curriculum decisions and priorities.

**Spatial skills in using computer graphics software**

Focussing specifically on the hypothetical study of Spatial thinking skills, it is worth noting the fundamentally 2-dimensional nature of almost all computer-based screen-display graphics. This could be a limiting factor in the attempt to develop solid or in-depth 3-dimensional spatial thinking. Model-making seems to be an obvious and important adjunct to any work which otherwise relies on flat on-paper or on-screen 2-dimensional images. Similarly it maybe useful to distinguish 2-dimensionally presented tasks which can be performed with 2-dimensional thinking, as opposed to those 2-dimensionally-presented tasks which actually require the student to think 3-dimensionally. (An approach to describing different features of spatial thinking tasks is discussed in Gough 1991.)

For example, students beginning to think about the movement of the 2-D Logo programming (e.g. LogoWriter, MicroWorlds, or Scratch) “turtle” on a 2-D screen can sometimes be seen getting out of their seat in order to look down or around in the way the turtle is looking in order to decide whether or not the turtle needs to be given a right or a left turn to make the next part of a drawing. This indicates a 3-dimensional response to a 2-dimensional task.

Similarly some of the Sunburst software packages which provide challenge and practice for problem solving in two and three dimensions often transcend the 2-dimensional restriction of the computer screen, and demand a 3-dimensional thinking response in order to answer questions about a tile being painted on one side and then turned over and rotated clockwise and painted or drilled in a different way (as in Factory and Super Factory) or a multi-story compound-structure building being seen from several different points of view, as in Building Perspective (these three software packages published by Sunburst for Apple IIe computers may now be somewhat outdated, but have not yet been replaced by comparable packages).

**Recognising the limits of the research**

Research hypotheses can be open-ended and as adventurous as the researchers choose. But some of the hypotheses or research questions may go beyond the limits of what is capable of being investigated, whether with full experimental precision or even with the more relaxed and less rigorous quasi-experimental design. When this occurs it is valuable to recognise it, and admit to the limits. For example, given natural classroom constraints, it may not have been possible to make direct comparisons between a class taught one way and a class taught another way, to say nothing about the difficulties of allocating students randomly to groups, or having a control group. But a research question about possible differences in the results of different teaching approaches remains a good question, and
the descriptive results obtained by looking at only one teaching approach may still remain as indicative of possible positive results.

Simply being honest indicates the need for further, possibly more rigorous research, and shows an awareness of research questions known but so far not yet considered. As all researchers know, often the hardest task is to find good questions worth researching. But not all questions are immediately researchable. Recognising the differences between the achieved, the possible and the still unanswered is itself a small step forward, and a warning against being too confident about what is being done. Moreover, as a small-step cyclic approach to investigating ways of improving educational practice, action research relishes such successive, limited partial steps forward. Clearly stating the current limits of what has been able to be researched so far, and what has been found out, helps identify future research goals.

Is this research really 'valid'?
Within the setting of such an action research approach to investigating classroom practice, what is 'validity'? What is 'internal validity'? The experimental concept of 'validity' is concerned with whether or not the things that are claimed to be evaluated or studied actually are being so considered. At this point we need clear definitions. In the spatial thinking research investigation example, an attempt to consider validity might involve discussing whether or not the curriculum, as developed, is genuinely concerned with spatial thinking. Inevitably this relies on some definition of spatial thinking. A test is 'valid' if it is believed to actually test the thing it purports to test: but what is it trying to test? how is it defined? However in this hypothetical case it seems that validity would not be such an important issue for the study, as long as what is described as involving 'spatial thinking' obviously does involve some kind of mental work with 1-, 2- and 3-dimensional objects and images.

Such matters of definition and validity are important in another way. Whenever we are trying to solve some problem, we are embedded in some present situation. Only when we have a clear sense of the situation can we see clearly enough in what ways the problem, and its associated concepts and questions, may be different. Woolly language is no way to make progress. For example, many schools are now attempting to implement so called 'profiles', which are meant to be a way of reporting on student learning in terms of so called 'learning outcomes' (exemplified by Curriculum and Standards Framework: Mathematics 1995). Outcomes-based curricula are all the rage. But what do such terms really mean? Are they different from the behavioural objectives (exemplified by Bloom's Taxonomy of Educational Objectives 1956) popular during the 50s and 60s? In what ways would a shift to outcomes-based reporting be different from the current practice? Too often teachers accept and attempt to implement, uncritically, whatever new package of concepts and language is handed to them by their institutional authorities, and out the window go various combinations of baby and bathwater.

It is especially important in considering computers in education (or any other similarly new curriculum resource) to be wary of bandwagon effects coloring or even preventing thinking. There is an increasing tendency to hear the word 'new' and think that this naturally implies 'progress' and 'improvement', and therefore the new whateveritis must be implemented because it must be better. Vitamin-enriched, enzyme-added, protein-boosted, … our mass advertising culture within our increasingly complex technological
and scientific world encourages such a view in the general public. Teachers also, in recent decades, have been encouraged to accept many changes in curriculum, materials, methods, workplace practices, administration and so on. Computers, with their extremely rapid and irreversible obsolescence simply force successive waves of newness on computer users and buyers, compounding these general expectations. We are reaching a stage where as soon as people, particularly teachers, hear the word 'computer' or 'Internet' they turn off the part of their brain which normally functions as a critic. Consider how unthinkingly the general public has embraced the march from 78 to mono LP to stereo LP, to audiocassette and finally, for now, to CD in recorded music. The same is often true in education. Moreover, those educational dinosaurs and luddites who see fit to protest against some latest great educational innovation can either be conveniently ignored, coerced to comply, ordered to shut up, or be sacked. (If one of us wants to continue listening to our 78s at home no one will stop us, though many heads will be shaken with disbelieving pity.)

Sheer novelty, as we will see in another setting, tends to make us enthusiastic. What is really at stake is the critical issue of validity. Just what is being offered, and what is it replacing? What do we gain from the new technology? And what do we lose? As another example, some teachers are rushing to embrace the so called 'talking book' (a CD-ROM which allows hypermedia-type interactive access to words, information, pictures, animation, sound effects and music), seeing this as a great step forward in the laudable drive to help children learn to read. But what does it really provide? Without voice-recognition a computer cannot listen as a child attempts to read aloud. Nor can an automated robot voice demonstrate good intonation and phrasing, nor pause to respond to a child's curiosity, nor recognise that a child is not listening to the story. A talking book can no more teach an illiterate child how to read than can any ordinary book. Not valid! What is a valid reading method, then? A human teacher, capturing the child's attention and enthusiasm, using good reading materials, sharing exciting stories, responding to the child's individual needs. It will be a long time before a machine can do better than that.

The same kinds of questions of validity apply to other forms of computer software. The most amazing computer graphics package is only a supplement, substitute for, or alternative to students learning to use paper, pencils, crayons, paint, and other visual materials. Hand-eye coordination, judgements about line, color, shading, and pattern need to be made just as carefully. Computer-based clip art is simply visual plagiarism, artistic piracy or vandalism, and may not play any meaningful or valid role in the children's development of graphics skill at all, despite the fact that the results can look stunningly professional. It will only be a matter of time before newsagents and card shops will not sell pre-printed cards, but instead will allow the purchase of a computer-printed design-it-yourself card that will require no designing skill whatsoever. When this occurs the personal and learning value of a child making his or her own card by hand will be incalculable. We say, of a child's clumsy efforts, 'It's the thought that counts'. We must always ask ourselves 'Where is the thought in whatever latest amazing gizzmo is offered as the latest great teaching technology?'. We need to keep our critical machine turned on all the time.

**Collecting research data from teachers and students**

As we attempt to establish changes and learning, apart from tests and test-like worksheet and related activities, where can useful action research data come from? Obviously teachers who participate in such a study should be formally and informally interviewed.
They are participants in the research, colleagues rather than 'experimental subjects'. However their involvement in the research will have considerable novelty for them, and hence involve them in much learning of their own. Hence their subjective reflections on their experience as participants will yield valuable qualitative data, extending information obtained from interviews with students and by accumulating students' writing about their experiences as well as collecting examples of students' own spatial and computer-based work. Also informal, unstructured observations of the behaviour of these teachers during the study can be included as data contributing to the material for any final report on the outcomes of the research. All of this teacher-related information is capable of showing where and how the teachers will have learned and have changed their attitudes, and developed new roles as teachers, classroom managers and facilitators of learning. Again, in examining change, in this case, 'teacher-change', it is important to have firm before-and after-statements to allow direct comparison, or attempt to specify or measure the apparent changes.

Inevitably, as children are learning they will make mistakes. Indeed, if no errors are occurring neither is any learning taking place. This means that recording and discussing students' errors in computer programming, software use, group discussion, student-teacher questions and answers, and pencil-and-paper-work and cardboard-and-scissors work becomes an essential aspect of this kind of action research. Analysis and discussion of 'errors' or (in reading terms, 'miscues') will shed any light on the student's spatial or other mathematical thinking. It is possible to make a 'diagnosis' of the faulty thinking that might then lead to a suggested or prescribed 'cure'. Think of the way we use students spelling 'errors' and reading 'miscues' to guide us in our attempts to help students learn how to write and read. Ann Newman has developed a 'diagnostic interview' for mathematics errors which corresponds to the familiar 'miscue analysis' of reading miscues (Newman 1977, 1983, Gough 1983). An analysis of student errors can form the basis for individual and group case study research, and can contribute significantly to any research evaluation of the implementation of new curriculum methods or materials.

How clear is my learning theory?

In our discussion of children learning, an important feature will be some account of how we believe children learn, and the evidence we see for this kind of learning taking place. Are we devotees of mastery learning? Do we subscribe to constructivist theories of learning? Are we unreconstructed Piagetians or behaviourists? Do we believe that the way children learn many school subjects resembles the psycholinguistic account of children's acquisition of oral language? Do we see mathematics learning as similar to scientific method or to language learning? How do we relate problem solving with the experimental processes of concept formation, skills development and attitude development? Have we been persuaded by Howard Gardner (1985) that children have multiple intelligences, and hence multiple kinds of learning? Where do we see left- and right-hand hemispherical dominance theories fitting in all of this, and so on? Such theories are like windows through which we observe and record what we think we are seeing. Our records will be more valuable if we declare our theories as part of our recording.

Also, depending on our particular learning theories, we will have different ideas about appropriate ways of evaluating children's work and learning, and different ideas about the proper role or roles of the teacher. As a very broad rule of thumb it is usual to suggest that
the best way to try to evaluate a child's learning is to 'test the way you have taught'. Indeed it can be argued that, if some method of evaluation is too remote from the teaching methods that were used, the children may not see any connection between what they have been learning and the assessment tasks. As a result their performance on the assessment tasks may not be indicative of their learning. This is another facet of validity.

Contrasting software for spatial learning

Now let us consider specific examples of computer software with spatial thinking aspects. There is a fundamental difference between LogoWriter and ClarisWorks in their respective ability to develop students' spatial thinking. With LogoWriter, regarding the turtle as a 'graphic cursor' which must be verbally instructed what to do, the actual word-based programming requires explicit verbal work to accompany thought. By contrast, the purely non-verbal visual performance skills required in ClarisWorks, using a graphics-tool palette in combination with the point-and-click style of tools-palette, and menu-based, mouse-driven graphics, make it possible for a student to do a great deal of visual work without having to put it into words. Instead the user simply looks, plans visually, and then performs the necessary actions, rather like using a robot pencil, or even just drawing by hand. ClarisWorks emphasises learning to do things spatially, whereas LogoWriter emphasises learning to think spatially and to be able to speak about this through the command words of LogoWriter's programming language. (Detailed discussion and suggestions about using a graphics software package in school classrooms are given in Susan and Graham Ferres' book *Mouse Art* 1998).

As a result of these two distinctly different ways of drawing, say, a rectangle, or a hexagon, LogoWriter stresses the verbal-mathematical and spatial link between angle and number of sides and total number of degrees in a full turn, along with physical ideas of moving (forward or fd) and turning (right or rt, or left or lt), and the step-by-step sequential nature of the drawing. In contrast ClarisWorks, at best, requires no more than the counting of the number of sides, and a little hand-eye coordination to place the drawing in the desired location and to make the drawing large enough. That is, LogoWriter is probably more likely to develop explicit verbal-based concepts, whereas ClarisWorks is more likely to develop largely non-verbal psycho-motor performance routines which may have very limited transference of learning to other situations away from the particular software package or from computer graphics. A child may know what to do with the mouse to make a rectangle, but may not know how to draw a rectangle, and may not have clarified the properties that distinguish a rectangle from a square, or a parallelogram.

ClarisWorks develops a fluent performance routine, whereas LogoWriter develops a coherently structured collection of related concepts. These are very different kinds of learning, and warrant close research investigation. One is what-and-how-to-do, the other is what-and-why-to-do. It would be interesting to discover which results in a more easily built-upon sequence of learning, and which is better retained, and which is more readily adapted to novel situations. It might be expected that point-and-click techniques are only useable in other point-and-click environments, and would be unhelpful for a student attempting to learn non-point-and-click spatial or graphics software, or even learning to use a pencil and ruler. Moreover, a sizeable time-gap in practising such performance routines might easily result in them being forgotten. By contrast the logical procedures in LogoWriter would readily adapt to many different kinds of programming and to related...
forms of mathematical reasoning, and even to physically moving through three-dimensional space as a human version of a LogoWriter turtle, like a line dancer. Moreover, their logical structured nature might make such programming skill last longer in useable memory.

Some of these differences might be explored through teacher and student interview, and might be observed in student behaviour, especially when one student tries to explain to another how to do something in either LogoWriter or ClarisWorks. Additional explicit verbal understanding of the spatial ideas implicit in the non-verbal use of ClarisWorks might be developed by asking students to write instructions for younger students to use in learning to draw particular shapes using ClarisWorks. We can attempt to gain insight to student understanding by requiring students to prepare draft instructions for using computer software, or other spatial materials. This can be improved by conferencing after trialling a draft set of instructions with younger students. Things which a more experienced student takes for granted will need to be explained to a beginner-student. For example: Where is the tool palette? What does it look like? How do you go to the Options menu? What would also be needed here is some explanation about pointing with the mouse, clicking and holding the button down, and then dragging with the button still down until the required option-command is selected and highlighted, then releasing the mouse to run the selected option. Confident acquired actions need to be turned, reflectively, into consciously chosen explicit words.

The same comments about ClarisWorks as a non-verbal psycho-motor performance skill software package also apply to KidPix, and other mouse-driven software graphics-tool packages, and equally to pencil-and-paper and scissors-and-cardboard activities which emphasise the development of particular performance skills, as a prerequisite for the development of spatial concepts and understanding of spatial relations between parts and wholes. In this case it is possible to ask to what extent a child is learning about the computer, or to what extent is the child learning mathematics which is implicit in this computer use? The perceived context and purpose for what is being learned can lead a child in quite different directions. This should become obvious through observation, discussion with the child, and related extension activities that explore the ways the child can transfer learning in one context or for one purpose to learning in another.

When people know they are part of an experiment

Any attempt to innovate, or carry out research, however relaxed in experimental rigour, however informal or gentle, should try to allow for the extra motivation that arises when using 'new' materials and activities. In education research the 'Hawthorne Effect' (McMillan and Schumacher 179–180; Ary et al. 226) means that, whenever you try something that is new, and the participants also know that it is 'new' and they are in some sense being 'guinea pigs', the innovation or experiment is likely to seem especially successful simply because it is at first a novelty. (The Hawthorne Effect is so named because it was first noticed in the Hawthorne plant of the Western Electric Company in Chicago, where researchers were attempting to find significant factors that could improve workers' effectiveness. Because the workers were aware that they were part of an experiment, regardless of what experimental changes were introduced, everything seemed to have a positive effect.) Incidentally, the fact that the Hawthorne Effect can arise in any innovation is not a justification for trying to conceal from students that they are involved in a new project or investigation. Indeed, usually it is impossible to conceal from students
any involvement in new activities or with new materials. Moreover as an ethical rule of
thumb, it is always preferable to be frankly open with students about what is going on in
their classrooms. Instead, be honest, and let the novelty wear off.

The apparent jump in enthusiasm and achievement that is observed when some
curriculum innovation occurs usually seems to diminish if sufficient time elapses for
students to become quite familiar with the seeming novelty. Unfortunately few education
research experiments last long enough (say, at least half a year, to a year, or longer) for
the Hawthorne Effect to wear off. Consequently the enthusiastic recommendation of a
short-term artificially boosted curriculum innovation rarely stands any realistic test of
time.

The miracle cure for weakness in learning fractions, the amazing results of introducing
cuisenaire rods, the stunning impact of calculators in classes (and so on), reported by
researchers who have implemented and observed several weeks of activity in a school,
may well turn out to have no serious long-term impact, once students become familiar,
eventually bored with the once-new ideas. The same effect also explains the
persistent dissatisfaction teachers experience with any curriculum method, or class
textbook, and the halo-effect they experience as soon as they introduce a new approach or
a new textbook, regardless of whether the new thing is in any way an improvement, or
even a serious change from the old. The result is that effective and valuable, but aging
techniques and textbooks are allowed to be relegated to the back of a cupboard or a
dustbin, simply because of its age. The moral is – beware of the superficially persuasive
impact of halos and hawthorns. Beware of bandwagons bearing amazing new gifts.

**Assessment of student understanding**

How can we assess students' understanding, in this context of spatial thinking? One
possibility could use a devious, or not obvious LogoWriter program to disguise what is
really happening, and ask the students to translate the LogoWriter procedure into a pencil
and paper diagram. This would be an excellent way of assessing students' spatial and
logical reasoning skills. For example

to draw this

\begin{verbatim}
lt 90 fd 30
repeat 3 [rt 90 fd 30]
end
\end{verbatim}

By this stage of trying to evaluate students' knowledge, many students would be familiar
with the idea that a `repeat 3 [other instructions ...]` command is connected with
drawing triangles – but here, where this is not the case, the students' understanding is
really tested.

There may be other ways that similar skills could be evaluated after students have
practised using ClarisWorks or other non-verbal performance-type graphic software. For
example, older students could be asked to prepare instructions for using the drawing tools
of a package such as ClarisWorks that younger students could use. Similarly students
could be asked to report on what they learned about, for example, triangles, or parallel
lines, as a result of their experiences using graphics software packages.

It should be remembered also that in the attempt to establish whether or not students have
changed, that is learned, as a result of their classroom experiences, they should have been
given some initial benchmark 'measurement'. Simply repeating these benchmarking
activities (which might have included worksheets, interviews, reflective writing, observed practical tasks, or even pencil-and-paper tests) will give some indication of subsequent change. Again, using the same, or similar 'pre-tests' and 'post-tests' helps to ensure validity.

Of course it is possible that students may vary considerably at different times in their ability to cope with any assessment task. This is the issue of 'reliability', where a 'test' with high reliability should give similar results under similar test conditions. Students tested once during a windy day may perform quite differently if they are tested later on a calm day. Similarly students tested at the start of a day may perform quite differently if they are retested at the end of a long hard day. Such day-to-day factors have the potential to complicate any attempt to evaluate student learning by comparing benchmark measurements, and teachers should be on the alert for such factors when they interpret 'test' results.

**Writing conclusions**

The conclusions of such a study may need to be couched tentatively. Where it has not been practicable, or where decisions have been made not to collect 'pre-test' and 'post-test' information it will not be possible to make large statements about the research having 'produced findings on positive effects', or the research having confirmed 'previous research work' unless the previous research is clearly cited and stands up to critical scrutiny, and actually bears comparison with the present study. As has been discussed, before-and-after benchmark data (either quantitative or qualitative) is necessary to argue the case that the research shows change, in students or classroom teachers. Similarly the research design must include different experimental treatments for different groups if we are going to argue that there is evidence that allows us to compare, say, computer-based approaches with non-computer-based work, or to say that this method produces enhanced results compared with the results produced by that method.

However at a descriptive level, we can simply tell the story of what occurred, speaking tentatively, but realistically about the broader implications of our results. Even though we may not be in a position to compare before and after, or one group with another, simple informal unstructured observations may be quite enough to suggest, or even demonstrate quite strongly (with some possible inflation due to the Hawthorne effect) that spatial thinking, or some other change which was the focal target of the action research) did or did not occur and personal confidence in students and their teachers did or did not develop from working with this computer software (or other new materials or methods). Often such descriptive results are as much as can be hoped for from action research. It only requires a few small extra details to move towards more rigorous qualitative research.

Finally, teachers should be recommended to write up versions of this kind of home-grown research. This should be distributed to all participants, and to a wider interested audience. Then, as Kemmis suggests (1994), the teacher-researchers should submit it to educational, subject-specialist and professional journals such as *Vinculum* and *Prime Number* (mathematics education journals in Victoria) for possible publication. Such publication serves as a guide for other practising teachers. It authenticates their normal professional activities, encourages them to take risks, to try new things, and at least keep up the proven motivation of novelty for its own sake.
References


**Ethics in Action Research: A Conversation**

From: "A Student"
To: <jugh@deakin.edu.au>
Subject: ethics of action research
Date: Mon, 4 Mar 2002

Hello, John.
I'm doing a PhD under X's supervision. I've just read your "Turning School Investigations into Valuable Research".

An issue you didn't touch on is the research ethics of Action Research.

My proposed research study is largely auto-ethnographical, a self-reflective analysis of my efforts as a reform agent in a number of roles.

During this final phase, 2002, I'm a deputy of a new high school which is using a curriculum organisation model I designed.

I have ethics approval for use of questionnaires and semi-structured interviews with teachers and students.

Since this phase of my study is really Action Research, I'd like to include "...informal, unstructured observations of the behaviour of these teachers during the study".

I find the issue of research ethics very problematical.

Must I get formal consent for such informal observations (which many might baulk at giving). Or can I ethically make such observations in a general way without formal consent of all players? Regards,

A Student

*****

Dear A,
you're absolutely right. I didn't touch on the ethics of Action Research for three reasons.

First, when I wrote the article I had not had as much experience in supervising students through ethics approval applications.

Secondly, the article initially grew from the discussion of a Masters-level research paper where ethical issues were not so important (or didn’t seem so, to me, at the time).

Thirdly, as the title of my article makes clear, I wanted to show readers/teachers how they could turn ordinary school activities into reportable research. This is easy enough,
within a school, where ethical issues are essentially identical to issues of teamwork and professionalism.

However, it should be noted that any formal research undertaken, AND REPORTED ON, FORMALLY (as in a Conference paper, or a published journal article) may need official approval from the “school authorities”. Here, exactly what constitutes “school authorities” may depend on your particular circumstances.

For example, if you were working in a Victorian (or other State) government school, you would need formal approval to conduct research (that is, to gather and work on research data or information — oral, written, or recorded by audio or video or interactive web-site — from teachers, students, or other members of the school community) from the school Principal, and from the Victorian government school authorities (the official name changes, from time to time, but think, here of the “Ministry of Education”, and find the current version of the name, and the appropriate official in the bureaucracy). You may also need written consent from all those who are participating in your research.

Similar comments apply, with appropriate adjustments in bureaucratic offices, if you are working in a Catholic school — in which case it would be the State or other headquarters for the Catholic school system — here think of the “Catholic Education Office”, or “CEO”, as the appropriate organization to approach, seeking ethics clearance to conduct research.

If, however, you are working in a private school, then probably the only formal institutional ethics approval you would need would be that of the school Principal, and perhaps the School Council or governing board.

But as soon as the would-be research is being conducted in a formal research setting, such as a university or as part of a university degree or a publicly accountable research project, ethical issues that can be taken for granted within the school’s do-it-yourself context of ordinary professionalism need to be treated more explicitly, and carefully, as you realise.

Hence your query is timely, and challenging.

I assume you have raised the issue with your supervisor (and I expect that he hand-balled the query to me). You might also raise it with the on-line discussion group of doctoral students that has recently begun. (Contact the Research Office of the Faculty of Education if you aren't aware of this on-line group.)

How would I answer your questions? Let me see.

You start by saying that your research is "auto-ethnographical, a self-reflective analysis of my efforts as a reform agent in a number of roles".

I realise that research can take many forms. In particular, as a reflective critical autobiographical narrative, it is possible that the research can focus on events which have already occurred -- dealing with your efforts that have already occurred, but not
hitherto been formally recorded or critically analysed, and that have not been fitted in a context of similar research and methodological literature.

That is, your research may deal with past events. If so, it is hardly possible to obtain retrospective ethical approval to allow you to conduct the research. It's happened. You are writing a history.

One solution may be to present what you know to be AUTO-biographical as BIOGRAPHICAL.

By concealing the fact that you are writing about yourself, you can totally conceal the explicit and implicit identities of people and institutions that feature in your discussion.

The word "conceal" is misleading. This is not a matter of dishonesty, but of formalising the reporting into a pseudonymous third-person reporting. It would be better to speak of “representing” the people and institutions in a particular way -- so that they cannot be identified.

Consider, as an extreme example, the way Julius Caesar referred to himself in the third person when he wrote his account of the wars in Gaul. Contrast this with the way John Holt writes about his own experience in the first-person, while ensuring that the names of children he works with are treated pseudonymously. Consider almost any other history or biography, where the personality of the historian or biographer is not seem to intrude, or be present at all. This can be achieved in such after-the-event research accounts of past events.

The central feature of this biography/history solution is the guarantee of anonymity, both personal and institutional. No one should be able to read your thesis, or any spin-off, and say, "Aha, the REAL author of this research is Andrew Seaton, therefore the Person X that Seaton refers to must really be Mr Whobody, and the school Seaton mentions as School Y must really be Uptown College".

But reading your outline more carefully, I don’t think that’s the kind of research you have in mind.

Your actual term for your proposed methodology is “auto-ethnographical”, and you extend this by suggesting it is “a self-reflective analysis of [your] efforts as a reform agent in a number of roles”. I’ve already offered a distinction between “autobiography” and “biography”, or even “history”.

But the conjunction of the “auto-” and the “-ethnographical” is puzzling, and possibly deceptive. Ethnography is about studying a culture, a “people”. How can this be an “auto-”, or “self-” study of a “people”?

What you seem to have in mind is a personal reflective account of a collective endeavour.

This is possibly better described using the expression “participant-observer”.
The expression “participant-observer” highlights the fact that you are a “PARTICIPANT”, that is, you are one of the people being studied.

As part of this you indicate there are a number of roles you play in, and corresponding critical perspectives you bring to bear on, the whole endeavour.

The expression “participant-observer” also states that you are an “OBSERVER”. As well as participating, you are observing, with all the usual ideals of would-be objectivity, impartiality and neutrality, that go with researchers “observing”.

Of course there is a tension, a potential conflict of interest, between participating and observing, between being involved and biased and subjective, versus being detached, unprejudiced and (scientifically) objective.

But as we know, “objectivity” is no more than an ideal that is unavoidably tinged with subjectivity. The defence against this is to try to be as frank as possible about biases, personal beliefs, and so on.

Is the expression “auto-ethnographical” widely used in the literature? How do others handle its ambiguity, and conflicting tensions?

However, rather than investigating past events, usually a (non-historical) research PhD takes a long time, during which the research events take place. You say that you are planning to report on events that have not yet all occurred, although you do say that some have already happened, such as the development of the new curriculum organisation. In this case a different solution is needed. There is time in hand to develop a case, beforehand, for obtaining ethical approval from those with whom you will be working.

This seems to be your situation. You WILL be administering questionnaires, and so on. So how WILL you handle any possible "...informal, unstructured observations of the behaviour of these teachers during the study"?

First, whatever kind of research data you plan to collect in the future, you MUST declare this clearly, ahead of time, to your intended subjects of research -- your colleagues, and students, and possibly even parents -- whoever may be a subject of "informal, unstructured observations".

Where anyone is unable or unwilling to give you permission to collect research data, no matter what you may experience with that person, you are NOT allowed to include any information that derives from that person.

You might be able to stretch this by speaking (with the usual anonymity in reporting) of informal or incidental evidence received in a pilot study, or from similar circumstances. But the research data so used should be incidental, rather than central to your main claims and arguments. If you DON'T have ethics approval for some research data, you can't pin your big research results on it.

The process, as with seeking approval for administering "questionnaires and semi-structured interviews", consists of developing a clear Plain Language Statement about
the kind of research information you might be gathering, its rationale, and the methods you propose using to ensure the information is used ethically.

In your case the situation is that you are managing, coordinating or otherwise involved in activities connected with your role as deputy-principal of this new high school which is using a curriculum organisation model that you designed.

If you WEREN'T doing a PhD you would still be working with teachers and students, and gathering data, and analysing it, and reporting on it -- but not as extensively as you will be for the PhD. Your ordinary work, with teachers, students and the new curriculum organisation model requires no formal ethical approval beforehand, and involves only ordinarily ethical professional behaviour.

Obviously that does NOT require institutional and personal anonymity in reporting.

But it DOES require that, for example, if you think the ICT coordinator in your school isn't toeing your line, or the Year 7 Language teacher is not a good teacher, you don't use your position as deputy-principal to take unfair advantages against these people. You follow due process, you behave professionally, you respect your colleagues.

Likewise with the students. You may find in an interview, or have it reported by a class teacher, that Minnie Dreggs in the Year 9 History class thinks the curriculum organisation stinks. You can't take steps that ensure that Minnie Dreggs gets a detention, or misses out on the otherwise well-deserved prize for raffia-work. You behave professionally, and so on.

I mention all of this because ethical behaviour in research is not that different from ethical behaviour in a profession.

But we tend to be extremely explicit in our handling of ethics in research, while taking for granted virtually the same issues in ordinary professional activities.

(Teams of teachers DON`T draft Plain Language Statements about what they propose doing, and how they are going to ensure that know one is mis-treated, and then invite potential participants to sign Participation Consent forms, before they start working together on some project. They are, however, professionally and legally answerable for their professional and public conduct in other ways.)

HOWEVER, parallel with this ordinary deputy-principal curriculum-organiser work, you are also doing this doctoral research. That is, as I have started to argue, only a few notches tighter, or more scrupulous, ethically, than the ordinary work.

The central issue in ethics (both professional and research) is minimizing or eliminating potential harm. Hence a first step is to try to identify potential causes of harm. Second, outline ways of avoiding or counteracting any such potential harm.

You ask whether you must "get formal consent for such informal observations (which many might baulk at giving)?" The answer should be clear. Yes, you must.
But if you present the request for the consent in a clear sensible context (such as, your new school, your coordinating role as deputy-principal, your central responsibility for the new curriculum organisation model, and the resulting activities that will be going ahead, anyway, as an ordinary part of school operations, etc.), and if you offer guarantees of anonymity in reporting (in your thesis, and any spin-offs), and professional objectivity and accountability and neutrality (presenting yourself as a co-worker in a joint-enterprise, rather than as a bureaucratic authority figure or "boss"), why would anyone baulk?

Finally, as I am sure you realise, action research is a do-it-yourself approach to research.

In your particular case you clearly highlight the autobiographical reflective nature of your research. But you also need to realise (as I'm sure you do) that your research is NOT just AUTO-biographical. You are telling other people's stories as well. Putting this slightly differently, the action research you have in mind is not so much do-it-YOUR-self as do-it-OUR-selves.

This means that your path through the remaining ethical issues involves reframing the research as a cooperative venture, so that you are a team-player who happens also to be the one telling the story of the team. It will be the team's story, warts and all, but told FOR the team.

Putting all this together the potential harms should be counteracted by the statements of intended team-work, the anonymous reporting, the neutralising of authority within the collective decision-making of the team ...

First, then, redraft your Plain Language Statement to include possible "...informal, unstructured observations of the behaviour of these teachers [and students! and parents?] during the study", along with the guarantees of anonymous reporting, fairness, impartiality, neutrality, ...

That shouldn't be too difficult. Feel free to use any part of this wandering discussion if you feel it might be helpful.

Many thanks for bringing your query to me,
John

*****

From: "A"
To: "John Gough" <jugh@deakin.edu.au>
Subject: RE: ethics of action research
Date: Wed, 6 Mar 2002

John
Thanks for your e-mail. I found your discussion interesting and helpful. I've been trying to resolve the ethics matter for a long time.
I accessed your article from Deakin's research web-site, and thought I'd try to get a comment straight from the horse's mouth, since you wrote about a research situation similar to the one I find myself in.

Some of the literature on auto-ethnography I've read is:


Ellis and Bochner say:
"Autoethnography is an autobiographical genre of writing and research that displays multiple layers of consciousness, connecting the personal to the cultural. Back and forth autoethnographers gaze, first through an ethnographic wide-angle lens, focusing outward on social and cultural aspects of their personal experience; then, they look inward, exposing a vulnerable self that is moved by and may move through, refract, and resist cultural interpretations..." (p.739)

Perhaps the thing I appreciated most about your "wandering discussion" was that it came back so quickly, and you were willing to spend some time to provide a considered response (and all for some bloke you don't know from Adam). Given the frustrations that have accompanied my distance learning, I can't tell you how much I appreciate that. Cheers,

A

******

Dear A,

thanks for your kind words. You are the first person to contact me regarding my article (Graham Ferres is listed as co-author, but most of the ideas came from me, as I was assessing one of Graham's students), so I was not only flattered but also glad to have the feedback, myself, and hence willing to respond as well as I could.

(I also used your message as a reason for not getting on with other pressing jobs. There's nothing like having an excuse for procrastinating.)

(I was guessing about Richard Johnson -- but as he also received a copy of my reply to you, you might check with him for his specialist supervisor's advice.)

OK, I'll confess I hadn't known if you had invented the term "autoethnography", because I'd never heard it before. My comments on it were comments made from considerable ignorance. But clearly you are familiar with it.

Obviously such an approach is hard to combine with Deakin's formal ethics requirements, as well as the team-work aspect of your particular situation.
You may want to write AUTO-biographically.

(And outside of formal ethics requirements, authors do this freely all the time, subject to libel laws, copyrights, and other public legal liabilities and responsibilities).

But doing so from within a school-teacher team, when you are in some ways the "boss" of other team-members, and you reserve the right (as researcher, and as boss) to be frankly critical of other team-members ... that is potentially, ethically, and professionally, problematic.

The result is that some other team-members may feel intimidated, and reluctant to continue playing, openly and honestly in the team. They may continue to go through the motions of being in the team. But they may actually be playing a deceptive game of please-the-boss, or worse, subvert or sabotage the boss's innovation.

As far as Deakin's ethics requirements are concerned, as I suggested, the best way is to try to draft a clear Plain Language Statement, admitting the risks of harm, and outlining your side of a team-work research-motivated contract to avoid such risks.

Having done that, you then hope to work as a team-member, trusting that the others in the team who have agreed to play, according to the rules of the team (and the PLS), will play fairly, so that the research data you obtain from them genuinely reflects their views, and their contributions to the team are as genuinely constructive as you would want them to me. Equally, where they may express criticism of genuine (unsuspected, or unanticipated) faults in the innovation (the subject being researched), you hope these willing team-members will be frankly and honestly critical, and not try to avoid trouble by saying things the boss might not like.

I'm sure I'm now simply repeating things I have said (hastily, and roughly) already, so I'll stop.

But if there are other matters you would like to discuss, please feel free to raise them.

I have been on Off-Campus student myself, and appreciate rapid replies and help. Apart from that, I regard teachers in schools as colleagues, and it is part of my job, as a teacher-educator, to do what I can to help my colleagues when they ask for it.

All the best with your research, and your ethics application,

John
Teaching as a Research Methodology: An Outline of a Process and Case Studies From Teacher Education


Central to the linked processes of learning, teaching, and researching, is the attempt to understand something: trying to make sense of experience — representing otherwise shapeless experience in terms of time, space, and words. The result is a “draft” communication, an emerging conversation between teacher-researcher, student-researcher, and emergent focus-subject-matter. What do we (think) we mean? What (do we think we) are doing? How can we express this in ways that others might understand? How does the struggle to find (new) words for (new) experiences affect our understanding of (new) experiences, and alter what we later do? Teaching, as an exemplar research methodology is also compared to the spiral-cycles of problem solving, and to action research.

Introduction

At the centre of the intertwined processes of learning, teaching, and researching, is the process of attempting to understand something — in fact, a major preoccupation of homo sapiens— making sense of experience. This requires a “draft”, which represents otherwise shapeless experience in structured accounts of time, space and images, and words. The resulting “draft” is an attempt at would-be communication, a tentative, emerging conversation between teacher-researcher, student-researcher, and emergent focus-subject-matter. What do I think I mean? What do I think I am doing? What do we think we mean? What do we think we are doing? How can I or we express this in ways that we and others might understand? How does the struggle to find (new) words for (new) experiences affect my or our understanding of (new) experiences, and alter what I, or we, do later?

I will not spend time, here, defining what I mean by “teaching”. Let me note, in passing, that for decades Bruce Joyce and Marsha Weil (recently joined by Emily Calhoun) have progressively developed a richer examination of distinctly different kinds or “models” of teaching, which currently are seen as falling in several major groups, such as:

- information processing models, including scientific inquiry, memorization, and lecturing;
• social models, including dyads and small groups, and role playing and values teaching;
• personal models, including non-directive teaching (facilitation) and development of self-concepts;
• behavioural models, including mastery learning, and direct instruction; and
• individual difference models, including learning styles, and socio-cultural diversity (Joyce, Weil & Calhoun 2004 pp. v–xii).

Yet despite the bewildering diversity of teaching models, Joyce, Weil & Calhoun almost provide a simple single definition of “teaching”, speaking, about “education” and “teaching” as processes that “build communities of learners” (2004 p 1) and saying that “Models of teaching are really models of learning” (p. 7), and that “education continuously builds ideas and emotions” (p. 6). They also say, with obvious circularity, that “real teaching is teaching kids how to learn” (p. 3).

As well as seeing teaching as a form of communication, teaching, as an exemplar research methodology can also be compared to the spiral-cycles of problem solving. Similarly teaching resembles action research.

The Brunerian concept of a “spiral curriculum” applies to both successive cycles of classroom cohorts, and to the longitudinal progression of individual cohorts across iterative versions of the same teaching/learning experience (Bruner 1960 pp 52–54). This “spiral curriculum” is also similar to the progressive cyclic nature of research. It moves incrementally from what we want to know now, through what we find out next, leading then to the identification of what further research may still be needed.

Teaching as a research process passes through iterative, interactive, evolving stages of:
• conceptual analysis;
• reflection on personal and social experience;
• critical review and analysis of existing literature on the focal topic;
• planning and material and methodological/pedagogical development;
• maintenance of running records;
• critical reflective analysis; and
• reflective changes based on feedback from research data; leading to
• the dissemination of research outcomes.

The Everyday Challenges for Teachers to Conduct Research

Many teachers at Primary, Secondary and Tertiary levels, and in non-school (or tertiary) settings (such as adult education and vocational and work-place training), are involved in professional development, curriculum innovation and similar tasks related to teaching, reporting and accountability. These may seem remote from ideas of 'educational research'. Traditionally there is a status-based divide between “those who teach” and “those who conduct research”.

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However by exploring the nature of Action Research, for example, and other research models it is possible to suggest ways that teachers can reflect more critically and constructively on professional activities to which they are unavoidably committed.

Increasingly teachers at all levels are asked to implement new ideas, new techniques of teaching, new curricula, and new methods of reporting. (Change, for its own sake, is often held to be a “good thing”. But beyond this, in an era of information explosion, and overload, faced also with a sometimes bewildering flood of new technology, changes are thrust on teachers.

Teachers are also professionally responsible, accountable to their students, the parents of their students, to colleagues, and to their employers. They have little choice about introducing change (for its own sake, or otherwise) into their teaching. How, then, can teachers try to ensure that the educational changes they are implementing are as effective as possible? Such a question needs careful investigation and reporting — it needs research!

How?

Telling it Like it is

At the simplest level a teacher can provide a brief clear account of what he or she is doing as clearly as possible. The result is essentially a “descriptive case study”:

• this is what I did
• this is why I did it;
• this is what I used; and
• this is what I noticed happening.

Such a report should include an account of what the teacher used to do, and why teacher thought it might be useful, or necessary to change from this.

From Descriptive Case Study to Action Research

With a little polishing this kind of simple, almost anecdotal description turns into a more developed form of “action research”. What kind of research is this? How does it relate to ordinary teaching events? What are the “actions”? [Note that parts of this discussion were first developed in a paper co-authored by Graham Ferres and John Gough, 1999, and published on the internet by the Deakin University Faculty of Education Research and Post-Graduate section.]

Action research has been rather grandiosely defined as “research undertaken by practitioners in order that they may attempt to solve their local, practical problems by using the methods of science” (Ary, Jacobs and Razavieh, 1972, p 36). In this definition, we may question the relevance of the “methods of science” (which emphasises scientific objectivity and demands the standard formal stages of “scientific method”, namely, defining a problem, stating a hypothesis, deducing consequences of the hypothesis, expressing these consequences in the form of some testable proposition or situation, collecting and analysing data generated in the experiment-like attempt to test the hypothesis, and evaluating the plausibility of the initial hypothesis in the light of the results of the test: Ary et al. p 37: consider, also
Campbell & Stanley’s account of “experimental design” for educational research (1963). Corey, a pioneer of action research less concerned with science, emphasized that research about schools (or comparable organizations) should be carried out in schools, by those who may have to carry out any changes that may result from the research (Corey 1954 p 8, cited in Ary at al. p 44).

In fact action research was first proposed for general institutional use by the social psychologist Kurt Lewin (for example, 1946) as a process of:

- cyclic study;
- diagnosis and therapeutic intervention which resembles a doctor's attempt to help a patient through successive cyclic stages of:
  - first ideas;
  - fact finding;
  - planning;
  - therapeutic action steps;
  - monitoring;
  - evaluating;
  - replanning;
  - and so on (Lewin's cycle is described in Burns 1990 p 253).

In Australia, action research has been recommended enthusiastically by Kemmis & McTaggart who define it as:

  a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the productivity, rationality and justice of their social or educational practices, as well as the understanding of these practices, and the situations in which these practices are carried out (Kemmis & McTaggart 1988 pp 5–6).

Clearly teachers do this the kind of thing all the time, sitting in staffrooms, talking shop, trying to sort out what they are doing, and how to do it better. The only remaining steps, apart from talking about it, is to document the institutional setting, the issues, and the talk, as clearly as possible, and communicate it to others. (See also McTaggart 1991, and Kemmis 1994.)

Teaching is not research unless it leads to wider dissemination of whatever has been learned or discovered (or simply investigated, analysed and described) to a larger community, including teachers and researchers. A “reflective teacher” may write long reports and fill pages of reflective analytic journals, and may make innovative modifications in his or her own teaching (which is certainly close to fully elaborated research). But without the move from “researching for oneself” to “researching and communicating to others”, it remains “teaching” — albeit good teaching, because it is critically considered, and moderated, but NOT (not YET) research.
An obvious problem arises as soon as a teacher begins trying to conduct research on what he or she is doing as a teacher. Unlike the intended objectivity of a scientist, psychologist or doctor who is (supposedly) dispassionately observing and evaluating events in the laboratory, or processes in the patient, teachers and educators who are doing (action) research ON themselves, are themselves subjective PARTICIPANTS in the events they are attempting to observe. They are identifying “strategies of planned action which are implemented, and then systematically submitted to observation, reflection and change ... [and they are] integrally involved in all of these activities” (Grundy & Kemmis 1981, cited in Burns 1990 p 252).

Not only is objectivity difficult, in action research (as in so much educational research, and in research, generally), so is the attempt to control all possible variables to gain scientific experimental rigour, and the ability to identify significant factors with certainty. Teachers use “research methods to study classroom problems”, a teacher “conducts the study or has an important role in the research process”, and, “because the focus is on a solution to a local problem ... rigorous research control is not essential” (McMillan and Schumacher 1993 p 21). Indeed, for ethical, and professionally accountable reasons, having a control group of clients (such as school children) which receives no treatment at all is obviously out of the question in any institution where professionals are paid to deliver some kind of observable accountable service to ALL their clients.

Given these definitions and descriptions, action research may be best thought of as normal professional work relating to a particular problem or research question, with a more focussed research-slant, actively probing definitions and assumptions, raising questions, examining different kinds of evidence, and implementing different kinds of practice in an attempt to find answers to the questions, and eventually achieve a solution to the initial problem. Equally action research can be used to investigate or critically describe the possibly unchanging (for the moment) status quo in a classroom or school, as Kemmis and McTaggart imply when they speak of action research investigating existing practices and situations.

Kemmis & McTaggart's *Action Research Planner* (1988) identifies four cyclic interacting major stages or “moments” in action research:

- planning;
- acting;
- observing and reflecting; and
- formulating new plans, actions, observations, … (Kemmis & McTaggart 1988 pp. 10–15);

which they also give, slightly differently, as:

- reconnaissance;
- planning;
- enacting and observing;
Following Lewin, they point out that action research is participatory, and proceeds in systematic but flexible cycles, starting small, investigating small changes, using collaborative theorising and critical reflection. Kemmis and McTaggart also outline four things that actions research is NOT, namely, it is:

- NOT what teachers usually do when they think about their teaching [although this is arguable];
- NOT simply problem solving [although their four stages exactly match the classic problem solving stages of Polya: 1945, pp. 5-6];
- NOT research done on other people, but research by participants on their own work [and/or also on their “clients”, surely!]; and
- NOT the “scientific method” applied to teaching: they stress there are many so called “scientific methods”, and action research is not just about testing hypotheses [but naturally, if only informally, it involves natural equivalents of hypothesis forming and testing] (Kemmis & McTaggart 1988 pp. 21–22).

They also suggest a plethora of common-sense guiding questions for analyzing and linking the four stages, such as:

- what are the key words and ideas you use in discussing this topic?
- what are some of the agreements and disagreements over these key words [this question is also referred to under the topic of “contestation”]; and
- what should my next action steps be? (Kemmis & McTaggart 1988 pp. 56–89).

They also distinguish three overlapping domains within which the research falls:

- language and discourse;
- activities and practice;

Contrary to Kemmis and McTaggart’s blanket statement that action research is NOT what teachers usually do, reflective teachers naturally engage with many aspects of action research. Moreover with just a little planning (as Ferres and Gough argued: 1999), teachers can straightforwardly turn investigations of teaching innovations at school, or about school, into a kind of “pilot-study research project”, possibly even with an experimental or quasi-experimental basis (as in Campbell & Stanley 1963), where a special “experimental treatment” class is compared, in more or less formal ways, with another class which receives a corresponding “traditional” or non-experimental treatment or instructional regime. Importantly, the more effort teachers put into written preparations for their (innovative) teaching, and the formative reporting of outcomes from their teaching (which is NOT the same as writing school reports for individual students, but the kind of professional reporting provided to colleagues), the closer their reflective, innovative actions come to fully developed research. To earn the description “research” this should also include the crucial quasi-final stage of “publishing” or more publicly reporting on research outcomes.
From Teaching to Research

The process of teaching sometimes directly generates research information of different kinds. But in what way is this really “research”?

We know that “research” can be understood as a process of investigating, or finding out, sometimes of “re-cognising” (that is, re-thinking, and/or re-conceptualising) as well as recognising seemingly novel situations as familiar materials, and, generally, the generating of new knowledge, or the creating of new understanding. As such, “researching” is very similar to “learning”, if not actually identical.

Naturally, then, teaching, which we know is closely related to learning, is, similarly, very closely related to research.

As already noted, teaching is a “praxis” or DOING component of Action Research, which is a well established and familiar research methodology.

Closely related to the instructional component of teaching is the assessment component. Formal assessment (such as marking essays, projects or assignments, or marking quizzes, tests and examinations), and informal assessment (such as talking with students, observing them as they work, and asking them to reflect on their own work-habits and engagement with the subjects being learned), readily generate research data about student understanding, misconceptions, learning styles, preferred intelligences, work-habits and attitudes to self, to others and to the subject at hand.

Informally, in the cut-and-thrust of teacher-and-student classroom interactions, or the on-line equivalent of internet-based “virtual” exchanges (in a “virtual classroom”), instruction and assessment may occur simultaneously. One statement may immediately require interpretation (to understand it), clarification (by further questioning and conceptual probing), and diagnostically monitored feedback (in the form of a reaction-statement). This is cut-and-thrust, indeed.

Teaching may also lead to conceptual refinement and clarification, and to better understanding of effective ways of producing new learning. It may also identify remaining difficulties that need to be resolved, or, alternatively, expose gaps in the curriculum that need new attention. Sometimes the very nature of teaching, with repetitive presentation of subject matter to successive cohorts of students, may result in a teacher deliberately seeking innovation in teaching method or in subject matter, if only to have some refreshingly new approach to what might otherwise be an unbroken career of “delivering” the one fixed subject (or textbook) for an entire working career, as per the fictional, but delightful “Mr Chips”. (Not that this should be taken as an criticism of what real-life Mr Chips do, and achieve: good teaching is good teaching, even if it does not change much across decades.)

But, importantly, where there is no change, and where teaching of a subject proceeds, year after year, with little modification in content matter, assessment, or instructional approaches, with the exception of minor adjustments in response to individual variation between students and class cohorts, there is much less scope, or use, for research, or teaching AS research.
Teaching (and Research) as Problem Solving

Consider Georg Polya’s familiar four-stage process of problem solving (Polya 1945 pp. 5-6: also Gough 2003). How might these apply to teaching, research, and communication? A table may help explore such comparisons. Note that where communication refers to “speaking” this should be taken as also indicating “writing”, as well as “picturing” (or other rendering of ideas only in forms other than prose).

Table 1
Comparing problem solving, teaching, research and communication

<table>
<thead>
<tr>
<th>Problem Solving</th>
<th>Teaching</th>
<th>Researching</th>
<th>Communicating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Look:</strong></td>
<td>Examine the context:</td>
<td>Where am I now?</td>
<td>What is the context?</td>
</tr>
<tr>
<td>— try to understand what the problem means</td>
<td>— what do I expect is already known?</td>
<td>— what is the current uncertainty and/or problem?</td>
<td>— the parties and/or speaker and audience</td>
</tr>
<tr>
<td></td>
<td>— what “should” they know, next?</td>
<td>— what is the research question?</td>
<td>— the subject for discussion</td>
</tr>
<tr>
<td></td>
<td>— pre-“test”</td>
<td></td>
<td>— the purpose of the discussion</td>
</tr>
<tr>
<td><strong>Plan:</strong></td>
<td>Prepare the next “lesson”:</td>
<td>How can I gather information that can resolve the current problem or answer the research question?</td>
<td>Draft (mentally) some of what might be said:</td>
</tr>
<tr>
<td>— devise a method that might lead to a solution</td>
<td>— content</td>
<td></td>
<td>— consider what might already be assumed</td>
</tr>
<tr>
<td></td>
<td>— method</td>
<td></td>
<td>— anticipate possible responses</td>
</tr>
<tr>
<td><strong>Do:</strong></td>
<td>Teach the planned lesson:</td>
<td>Carry out the research:</td>
<td>Talk, and listen to other’s talk</td>
</tr>
<tr>
<td>— put the plan into action</td>
<td>— be flexible</td>
<td>— gather data that could answer the research question</td>
<td></td>
</tr>
<tr>
<td><strong>Check:</strong></td>
<td>Assess progress:</td>
<td>Assess the use of research data as a defendable answer to the research question</td>
<td>Monitor talking, and responses to talking:</td>
</tr>
<tr>
<td>— consider whether the attempted solution has worked</td>
<td>— monitor responses to teaching</td>
<td></td>
<td>— do I make sense to myself?</td>
</tr>
<tr>
<td></td>
<td>— post-“test”</td>
<td></td>
<td>— does my “audience” understand me?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>— do I understand my “audience”?</td>
</tr>
<tr>
<td><strong>Cycle back, as needed, on the basis of critical examination, through any previous stage</strong></td>
<td>Cycle back, as needed, on the basis of critical examination, through any previous stage</td>
<td>Cycle back, as needed, on the basis of critical examination, through any previous stage</td>
<td></td>
</tr>
<tr>
<td><strong>“Report” on success, or otherwise of solution attempts and possible solution(s)</strong></td>
<td>Report, to students, parents or guardians, and colleagues</td>
<td>Report on (&amp; “publish”) research outcomes, and plans for further research</td>
<td>??? and/or “publication”</td>
</tr>
</tbody>
</table>
Simple as this is, it suggests commonsense commonalities. Of course, it does not provide fool-proof methods for conducting cutting-edge research, solving all possible problems, being the world’s best teacher, or being a brilliant communicator. These stages are not recipes, but low-level analytic descriptions of processes.

Note also that a possible fifth column-category could similarly describe cyclic stages of LEARNING. Although Polya, in particular, saw problem solving as an aspect of DOING mathematics, Robert Davis, using information processing theories, elaborated Polya’s four simple stages into seven stages, as part of an analysis of how people learn (or generate either new concepts, or new skills: Davis 1984 p 306: on pp 366-367 Davis expands the seven steps to ten steps, without significantly altering the general strategy: also Gough 1997, and Gough 2001).

Similarly (as I have suggested earlier: Gough 2003) similar stages can be seen as applying to curriculum development, OR, expressing the same idea slightly differently, curriculum development can be located within a broad process of teaching, along with ASSESSMENT as another component or aspect of teaching.

Through all of this, critical reflective examination or assessment or monitoring is a crucial component, Similarly another essential preparatory component is the researching of background, whether conducted formally, or informally (I have also argued earlier that critical examination and archival investigation are major aspects of research: Gough 2000, and Gough 2001.)

**Case Study 1: Conceptual Analysis and Identification of Process — Diagnosis of Spelling Errors**

In an earlier stage of my teaching career I once found myself in a room of teachers, attempting to teach, by demonstration, how to diagnostically analyse spelling errors, using the “Diagnostic and Remedial Reading Spelling Record Sheet” (Peters, 1975, Appendix A, pp 38–39). This involved taking spelling errors (appearing, for example, in a prose dictation task: Peters provided three age-graded examples: pp. 24–26), one at a time, out of context, and assigning it to one or more categories, such as:

- substitution of letter strings: (a) phonically reasonable (b) not phonically reasonable;
- faulty auditory perception;
- perseveration [i.e. repeated occurrences of the same “error” despite teacher-intervention: and/or mechanical repetitive writing of the same letter or letter cluster];
- omissions or contractions;
- insertions;
- transpositions;
- doubling; and
- unclassifiable.
My attempted lesson broke down as successive words were allocated to several, sometimes most or all of the available Peters categories. Moreover, when the teachers asked what remedial USE would be made of the resulting analysis, despite my preparedness to teach this lesson, and my close familiarity with Peter’s ideas about spelling, I realized, in the act of teaching, that there was no direct link between any process of spelling, or a process of teaching (and/or learning) spelling, even though Peter’s provided an interesting flowchart for “Remedial or First Spelling Programme” (Peters 1975, Appendix C, p. 44).

I felt compelled to abandon the rest of the lesson, and slept little that night.

The solution emerged, fortunately, in time for the following lesson. I expounded a new method for analyzing spelling errors, based on a linked combination of language theory, spelling process, and instructional approaches.

Diagnostic questions guided the teacher’s analysis of the sample of spelling attempts:

- has the student proof-read his or her writing?
- does the spelling error sound right, or nearly right, or mainly wrong, as sound?
- does the spelling error look right?
- should this mis-spelled word be expected to be known as automatic spelling for this student?

Each question led directly to suggestions for the teacher to pursue, either seeking further information, or intervening in some instructional or remedial way. I do not claim that my method is the best, nor do I believe that it was ever widely adopted (spelling quickly fell off the must-do curriculum agenda around this time, and in our troubled era of spell-checkers has not yet found its rightful, important place, in the so-called Literacy curriculum — that is my view). But I do suggest that it is useful. Moreover, versions of this new method were published (e.g. Gough 1978, 1979, 1981).

My newly developed diagnostic approach was based on the theoretical and practical results of psycholinguistic researchers, who had been investigating methods of teaching students how to read, and practical methods of diagnostic analysis of reading errors, linked directly to theoretically sound and practicable approaches to reading remediation. The psycholinguistic research breakthrough occurred when language and oral language processes were better understood, and when researchers investigated and described the actual reading practices of competent adult readers. An invaluable experimental device was the use of bi-lingual texts, used to analyse the use of underlying meanings by bi-lingual speakers and readers.

In my case the teacher-research result was that a new process of (child and adult) spelling was identified:

- reliance on automated fluent handwriting;
- use of visual memory to check the look of a target word;
- etymological analysis of word-roots, and stems, to check the meaning of the target word; and
• letter-sound skills used as a last resort to obtain a phonetic approximation, thus enabling other proof-reading skills to be used, as well as dictionary referencing.

This spelling process highlighted the importance of proof-reading, and the serious difficulties of proof-reading one’s own writing, when the usual fluent reading process was known to handle inferred and intended meaning, rather than literal letter-by-letter and word-by-word checking of a code. Let me add, by way of catching up, that this approach can be applied also to the currently notorious problem of over-reliance on spell-checkers that are unable to pique the rite word that is kneaded for the contest. Tri it yore selves. Its knot sew sample wenn ewe daunt no howe.

Case Study 2: Teaching in an Era of Changing Computer Software

Eight years ago I reported the start of fresh research, a self-study based directly on teaching, where the curriculum content was Logo programming, within the software environment of MicroWorlds. What had started as MicroWorlds version 1, has passed through several 1.something iterations, and several 2.decimal versions, and is currently available in several PC or Macintosh alternatives. Despite this, and behind the cosmetic changes to the user-interface, the major intellectual concepts, and purposes of Logo programming remain fundamentally unaltered. Oddly, as I write, the anticipated view that Logo would simply go away, because it is OLD (and we all know that “old” means BAD and/or DISCARDABLE), has not proved to be correct. The more schools equip themselves with computers (or adopt a lap-top policy for all students), the more they come to Logo (in the current form of MicroWorlds) anew, or return to Logo.

Nonetheless there are some important matters that arise in MicroWorlds that had not previously featured in most earlier versions of Logo, such as LogoWriter. These include:

• the use of the command dotimes, which is a version of a repeat command with a built in counting-variable;

• command words such as launch, and, importantly, forever, which enable parallel processing; and

• the challenge to older-style programming skills that had previously required careful use of local variable, the deliberate avoidance of global variables, and the use of recursion.

Here the research exists in the teaching, the interaction between instructional material (provided on-line, and on paper) and students’ drafts of Logo programming, and in the progressive, constructive refining of Logo possibilities. Importantly, what would otherwise be no more than “teaching” becomes “research” when it is more widely published, as is the case (e.g. Gough 2004). While less of this research is publicity published (partly for lack of suitable refereed journals, and because of the temporary nature of printed books for rapidly changing software), as noted already, the feedback from research (based directly on teaching) to teaching itself, is an instance of action research, at its most fluid.
Conclusions, for the Time Being

I am not claiming that teaching IS research. But I have tried to argue that, approached in special (natural, and not excessively arduous) ways, teaching can be a form of research. Importantly I have also tried to argue that, for teachers considering embarking on higher degree or other research, unsure what “research” might consist of, if they understood better how many aspects of their familiar teaching tasks are strongly research-like, and how readily they could extend some of these so they become fully developed research, the more confidently they could take those first tentative steps from being “teacher-only” to “teacher who is also a researcher”.

Hence I argue that many more people — teachers, particularly — COULD be active researchers IF they started to recognize the possibilities for drawing directly on everyday teacherly activities, and exploited these, for the sake of increasing professional knowledge about teaching, learning, and education generally, and for the special sake of becoming better teachers.

Many of the points I have made are little more than common sense, made explicit. In the same way, action research itself, is essentially common sense, writ large: how to set about tackling long-term complex (team-handled) undertakings as openly, reflectively, and constructively as possible.

But this should not be seen as trivializing the argument. Nor can common sense be alluded to, and then left, accepted as necessarily correct because it is held to be “common sense”. Instead it needs always to be critically examined. What is common sense for us, here, now, may not be sensible, in any way for other people, in other places, at other times.

Our own everyday naturalistic understanding (“common sense”) should be problematised, and, maybe, even, queered. But this “contestation” is never for the sake of being difficult, or archly playful. It is, precisely, with the goal of recognizing that human knowledge, such as it may be, is inherently subjective, tentative, unreliable, and requiring continual critical scrutiny, however obvious, and taken for granted and “common sense” it may seem, initially to be.

The goal is to know more, however tentatively, and to do better, however fallibly — or to do what we believe to be the best we can, given our finite, frail human circumstances.

References and Further Reading


Ferres, G., Gough, J. (1999). Turning school investigations into valuable research


Curriculum Development as Research


The words “research” and “teach” are different. Higher status is often given to “researcher” over that of (mere) “teacher”. This paper argues that good teachers are researchers, yet curriculum development as a form of research is often undervalued, neglected, or ignored. Curriculum development includes these aspects of the research process: critique of the background of the research data (evolving curriculum and socio-cultural contexts); conceptual analysis, definition and demarcation; critical collection of literature; development of information-gathering tools (assessment instruments), and monitoring of subjects’ reaction to drafts of the focus topic. Examples are drawn from the author’s curriculum development for a Masters-level unit on assessment in education and training.

Curriculum Development That is NOT Research

Not all kinds of curriculum development constitute research. For example, when there is little real “development”, such as the hypothetical case that a teacher in a school is told that he or she will be teaching Year 8 Mathematics using a new textbook called Super Maths 8, and, importantly, the textbook and/or its curriculum content, is similar to what the teacher has previously taught or even to what the teacher experienced while a school student. This teacher will certainly need to “develop” a suitable sequencing of classroom instruction and activities, as well as assessment tasks. But the actual work could be summarized as “more of the same”.

Certainly there is greater scope for “research” as the teacher attempts to establish an optimally effective match between his or her instructional activities and the work habits, attitudes, and learning engagement of the actual students. What are their needs? How well are they engaging with the challenges of the curriculum? If the intended progress is not satisfactory, or is greater than anticipated, what might the teacher do?

But this might be better described in terms of “teaching” as a “research methodology”, which I hope to explore in a future Symposium presentation.

When Curriculum Development CAN be Regarded as Research

A crucial ingredient in curriculum development being a form of research is the “newness” of whatever curriculum is being developed. However this is not as simple as it might initially seem. Seemingly new ideas can be tricky.
The Ambiguity of Words — “Authentic Assessment”, Anyone?

Plain words are easy to string together, with a resulting semblance of being meaningful, partly because they are at least grammatically well framed, and also because their plain meanings seem sensible. Despite this the words may not mean the obvious things we intend.

Consider, for example, the technical term “authentic assessment” (e.g. Emmitt 1999). This seems both appealing — we naturally want whatever we might do in the name of assessment to be “authentic”, rather than spurious — and immediately clear. Yet in my experience this term has been notorious for its misinterpretation by students who grasp only the plain language appearance and ignore, or misjudge the technicality.

In fact the term “authentic assessment” has appropriated to itself (that is, it has terminologically highjacked!) the generic and honorific or meritorious everyday connotations of genuineness.

This does NOT mean that any other form of assessment is unauthentic! Far from it.

The technical definition of “authentic assessment” is that it is based on so called “authentic activities”, namely those that aim to achieve real-world, purposeful, practical goals. These are the kinds of goals that real people pursue in real life.

For example, if we consider a school situation, an “authentic task” might be having students (with some teacher support, or other adult consultation and guidance) organise a school dance, or manage a school cafeteria, organise and edit and publish and sell a school newspaper, or investigate the costs of and lead a school excursion.

Such activities might include considerable planning time, committee work, and the drafting and revising of working documents, preliminary plans, running reports, final reports, schedules of events, maps, trial runs, market research, costings, balance-sheets, and so on. The assessment might focus on any aspect of the activity, including the running of committee meetings, the preparation of a project budget, the drafting of a proposal, and the final publication of an audited financial and descriptive report on the project.

We can contrast this with a rather ordinary class lesson, or sequence of lessons, on, say, cafeterias, or newspapers, which might include students researching the topic and writing class reports. Such activities are clearly attempting to “simulate” or “model” what might otherwise have been “authentic” — really doing it! Alternatively consider other less obviously practical classroom activities, such as completing a worksheet of 4-digit multiplications, or solving quadratic equations.

Consider, as an alternative, a non-school setting, such as an auto-repair training centre: an “authentic activity” might be actually working on a car. By contrast, simulating this, with textbook activities about fuel supply, ignition systems, piston design, and the physics of disk-brakes versus pad-brakes, would be far less “authentic” — and, according to the technical definition, NOT “authentic” at all!

I will pass over without comment other potentially deceptive and misinterpretable technical terms as “enactivism” and “autopeosis” (e.g. Maturana and Varela 1980, and Begg 2002). Note that I am not suggesting that these authors are in any way unclear in their use of these terms. But again, in my experience, their readers are often less clear.
Certainly “enactivism” has little to do with “enacting” as it applies to the promulgation or implementation of a new law or statute. Equally “autopoesis” has little to do with “poiesis”, the making of poetry, unless we stretch the words and their cargo of meaning to aesthetic eccentricities such as Gerard Manley Hopkin’s mystical-religious concoctions of “inscape” and “instress” as attempts to use words to capture the essence of existence, and the being of an object or an organism.

**How New is New? And How Could We Know?**

The idea of newness or novelty is itself inherently problematic.

Any new thing is related to, and built on existing ideas and skills. To the extent that a potentially new idea is really new, it must nonetheless be understandable in terms of older existing knowledge. Otherwise we have no context within which to interpret it. Utter novelty, if we can imagine such a thing, is alien to what we know.

We learn and understand, precisely, through what we know.

Q: What did Tarzan say when he saw the elephants coming?
A. “Here come the elephants!”.

Q: What did Jane say when she say the elephants coming?
A. “Here come the bluebirds!” (Jane was color-blind.)

Q: What did Tarzan say when he saw the elephants with sunglasses on, charging down the path?
A: Nothing. He didn’t recognize them.

(Blake, 1964, pp. 8, 9, 14.)

What I know, and can do, shapes what I think I see, how I interpret a situation, and how and what I am able to learn. I recall a toddler who was given his first toy gun by doting parents. He looked at the shiny metal, and pondered how to use it. Then placed it flat on the floor, and pushed it backwards and forwards, making his usual toy-car play-noises: “Brrm! Brrm!”. In this child’s mind, if in doubt, treat it like a familiar toy car.

This broad theory of knowledge, and related learning, is fundamental in cognitivist, constructivist, information processing, and similar theories, as I have repeatedly argued (Gough 1997b, 2001). All human ideas are built on a personal, cultural, and biological foundation of “analogy” and “metaphors”.

Though analogy is often misleading, it is the least misleading thing we have.” (Samuel Butler [1835-1902]: from Notebooks, in “Music, Pictures and Books: Thought and Word 2”; cited in Cohen & Cohen 1960).

Looking beyond the theoretical — conceptualizing, analytic and descriptive — learning and knowing is fundamentally grounded in biologically inherited schemata, or “concepts”, or “metaphors” (e.g. Skemp 1971; and Gough 2001b).

Even sophisticated ideas are built on a framework of very, very simple ideas — the kind of things we learn when we are two or three years old (Davis 1981 180-188).

These underlying building-block concepts are the kind of gene-linked brain-skill hard-wired biological forms of knowledge we have, from birth, because our species evolved to attend to such “concepts” as “in”, “out”, “beside”, “above”,

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The point, here, is that our biological bases for knowing, and for learning, and for creating “new” concepts, constrain us, and limit the achievable newness. We CAN be creative, but we do so within the limits of our species.

“Numeracy” is New, and Means ...?

A current operational litmus-test of “newness” is whether or not our wordprocessor’s spell-checker accepts a word as one of its known words. The word “numeracy” is a case in point, still unaccepted as a REAL word by the software I am using to compose this discussion. Clearly the intention is that “numeracy” is the “number-related stuff, and maybe more, that corresponds to the well established language-based term “literacy”.

There is a natural temptation to link these with the traditional Three Rs — Readin’, ‘Ritin’ and 'Rithmetic. But nowadays the term “literacy” is stretched to the “reading” and “writing” of film, and multi-media, and computer-screens, and internet web-sites (for example, see Chandler & Gough 1999). Similarly, just as “mathematics” is now seen to include far more than number-only ”Rithmetic (which might be equally expressed as “numberacy”, to emphasise the number-focus limits of the usage), it is important to see “numeracy” as including such NON-NUMBER-related aspects of mathematics as measurement, data-handling and statistical analysis, probability and random events, spatial thinking and geometry, logical reasoning, and problem solving.

These issues arose when I joined a Deakin University team developing (curriculum development!) a new compulsory under-graduate Secondary-teacher-training one-semester unit Numeracy Across the Curriculum with colleagues Susie Groves, Peter Grover, Ron Smith, and Helen Forgasz. In my mind, at least, a central difficulty was to distinguish, conceptually, and in practice, numeracy from literacy (both are a form of understanding and communication). Equally I needed to investigate and clarify the questions:

What is “numeracy”; and in what ways is it different from, and in what ways is it related to the large body of knowledge we know as “mathematics”?

a challenge for you to consider.

Consider this: Imagine a a Venn diagram whose “universal set” shows all Human Knowledge — the totality of what humans know. Outside the universal set are things that humans don’t know, as well as things that are not knowledge of any sort — physical objects, for example, events such as a wind blowing, cloud in the sky or a wave on the surface of the ocean. There are also other forms of knowledge, such as how to detect the identity of each member of a dog pack, by smell, or how to navigate from Northern Siberia to the south coast of Australia — canine knowledge, migratory-bird knowledge, and other non-human kinds of knowledge.

Within the universal set are smaller sets, each of which represents some specific branch of human knowledge. These include such traditional branches of knowledge as Music, Art, Ballroom Dancing, and How to Drive a Car, or How to Bake a Sponge Cake, as well as Knitting, Skateboarding, a Linnean taxonomy of plants and animals, Mendelev’s Periodic Table of Chemical Elements, and so on. Somewhere in this,
possibly overlapping some of the other branches of knowledge is MATHEMATICS. Somewhere inside “mathematics” is the smaller sub-set of “school mathematics”.

Obviously some aspects of how-to-bake-a-sponge, for example, overlap with aspects of mathematics. But let us accept the broad distinctions between knowledge which is essentially mathematics, and other knowledge which may be investigated or enriched by mathematics, but which is not, in itself, essentially part of “mathematics”.

Here is the challenge: where in this Venn diagram do you draw NUMERACY?

Equally, what aspects of knowledge are OUTSIDE wherever you draw the boundaries of numeracy? Do any parts of numeracy fall outside mathematics as a body of knowledge?

(If this is easy to answer, or irrelevant to your interests, consider a parallel challenge. This time the Universal Set is Human Communication. Some of this is oral, some is verbal-written, some is non-verbal/non-oral postural and gestural and facial. Somewhere inside this universal set is Reading and Writing — the first two of the traditional Three Rs. Where do you draw a boundary that would contain LITERACY, inside, but leave outside other aspects of human communication that are not considered part of Literacy?)

The continuing process of seeking plausible and convincing answers to these questions was, and is, a piece of research (successively reported in, for example, Gough 2001c, 2002a, b, c, 2003a and b).

One of the continuing complications here is the evolving impact of new information and communication technologies (or ICT — namely, computers, computer-based resources, and the internet, as medium for communication and as information resource) on curriculum and classroom instructional methodology that had previously relied exclusively on pencil-and-paper working, paper-based books (typically, textbooks), not-s-dynamic chalkboards and human teachers.

Just as literacy necessarily expands to include skills needed to handle new media, such as CD-ROMs and web-sites and DVDs, equally numeracy, and “school mathematics” as a curriculum, needs to expand to include skills needed to handle spreadsheets, programming languages, dynamic geometry software (such as Cabri Geometry and Geometer’s Sketch Pad), and generic mathematics-processing software (also known as Computer Algebraic Systems, or CAS — such as Maple, Derive, and Mathematica — and increasingly incorporated in graphic calculators).

My own conclusions are that:

**NUMERACY” IS (MOST OF) PRIMARY SCHOOL MATHEMATICS, USED OUTSIDE THE MATHEMATICS CLASSROOM.**

This tells me that numeracy is contained WITHIN (in set-theoretic and conceptual terms, “properly within”) the larger curriculum of school mathematics, which is itself properly contained within the whole large body of subject-matter knowledge which is “mathematics”, ranging across history and cultures and uses.

It also alerts me to the fact that it is a collection of lower-level mathematics skills that are used widely in other non-mathematics school subject areas (so called KLAs, or Key Learning Areas), and also outside school altogether, in everyday life at home and in recreation, and in ordinary non-specialised non-technical aspects of adult work.
This is in fact a conceptual paradox that in my experience confuses some people. Numeracy, as I define it, and as many people think of it, is strictly SMALLER, as a body of knowledge, than mathematics. But is used almost UNIVERSALLY in everyday living. By contrast “mathematics” is used, in highly technical, but usually fragmentary or limited small-scale ways in the contexts of specialist trades — accounting, engineering, physics, and so on. That is, the smaller subject-matter is used more widely than the larger.

**Curriculum as a Concept or Topic for Research**

Sometimes the researching that needs to be undertaking is a kind of conceptual clarification, possibly linked with the devil’s advocacy or critiquing I have also outlined as a research methodology (Gough 2000), as well as possible academic “archaeology” (Gough 2001d). In this case, while discussing “curriculum development” as a form of research, in a self-referential way, one of my current challenges is to be a team-member developing a new Masters-level unit on “curriculum”.

An obvious, simplistic question, then, is: What IS “curriculum?

The equally obvious, traditional answer, is that it is some body of knowledge that is to be taught.

However many of my colleagues dismiss this as simplistic and out-dated. Taking such a definition for granted, they move to see curriculum as a collection of problems and dilemmas, linked to underlying theories, cultural negotiations and conflicts, and political/historical movements.

Curriculum, as a body of knowledge is not left in isolation, as a book on a shelf that a teacher might take down, open, and use to instruct a class. Instead curriculum (such as a textbook, and related background materials, as well as supporting instructional materials and classroom activities and learning experiences) is problematically embedded in fraught, uncertain human contexts:

- who is the curriculum made for?
- who made the curriculum?
- for what purpose, or for whose purpose was the curriculum made?
- how is this curriculum to be understood in terms of gendered views of human experience, ethnic diversity and tensions, religious beliefs and ethical values, political policies and principles; …

and so on.

**Curriculum Development (Research) Is Needed Where Curriculum Changes**

Whenever there is a move to change curriculum, fresh research, including curriculum development, is necessary. Currently this applies, for me, with continuing changes in Logo programming software, notably, as MicroWorlds replaces LogoWriter, and, itself, moves to fresh versions of MicroWorlds (for example Gough 1996). What can current versions of MicroWorlds do, and how can this potential be effectively matched with the interests and needs of the students I teach (many of
whom are themselves school teachers engaged in teaching school students Logo programming)?

Similarly in the area of mathematics education, especially at Secondary and higher levels, this present era of scientific calculators, graphic calculators, dynamic geometry software, and mathematics processing software (also known as Computer Algebra Systems, or CAS), radically challenge traditional sections of the Secondary mathematics curriculum: trigonometry, graphing, statistics, and even algebra. If software can solve any (many) equations we can correctly type out, what need is there for students to develop pencil-and-paper algebraic computation skills? (Similar arguments were outlined, with further application to the impact of wordprocessing, web-sites and the internet on reading and writing: in Chandler & Gough 2000.)

Curriculum Development: A Mini-Case Study — “Exemplary Assessment”

Several years ago I embarked on the development of a new Masters-level coursework unit on Assessment. Working with a team of Deakin colleagues I struggled with the fact that the previously used technical terms “assessment” (= educational measurement) and “evaluation” (= diagnostic interpretation of educational measurements) had been modified by the free-handed appropriation of the interpretative term “evaluation”, now used to apply to the structural and performance evaluation of educational programs and institutions.

But that was only one of the early problems in this curriculum development. After much discussion and development the team also negotiated the assessment activities to be used in this unit on “Assessment”, one half of which was an investigative critical essay on the briefly expressed topic:

The theoretical underpinnings of exemplary assessment and its application in context.

We successfully taught this unit for the first semester, using on-line communication to support the off-campus correspondence “teaching-by-remote-control”.

But it was our own students, later, who raised a major question: — What is exemplary assessment?

What did we have in mind when we used that pejorative, honorific term in the essay topic? Certainly we wanted our students to focus on the best assessment practices they could find, and, as far as possible, on current or recent practices, rather than to waste their time considering outmoded or weak and criticisable forms of assessment. We wanted our unit, and our students’ learning about assessment, to be concerned with “best practice” and to be seen to be at the “cutting edge”. Naturally.

But we had not examined our own brief, bland exhortations to our students.

Faced with their queries — what do you mean? give some examples — as convener of the unit, I had to think fast and hard — and try to keep the customers happy. I also had to attempt to live up, in the assessment practices being used by this unit, to the best advice the actual unit’s content material provided.

The situation was all the more demanding because it was self-referential: how can a unit on assessment best assess its own students? What exemplary assessment role-model does a unit on assessment offer these students who are learning how to assess
— and to criticize — assessment processes? Would we be hoist with our own petard?
(Incidentally, this is an interesting, and challenging image, usually from Shakespeare:
Homework: What is a petard, and how and who might it hoist?).

In fact I had to develop some new (new for me) curriculum. The following
discussion summarises my conclusions.

What is exemplary assessment in or for a particular context?

Obviously the “context” is someone’s own particular work-place situation (e.g. a
school, a TAFE or polytechnic, a large industrial company where staff are involved as
instructors in on-the-job training, a hospital, etc.).

The word “exemplary” is harder to pin down. It means what it says — assessment
that is an outstanding example of its kind, in its own particular setting. We can also
think of terms such as “state-of-the-art”, “cutting-edge”, “best practice”, or “quality”.
All of these capture the general idea of “exemplary”.

However, what does “exemplary” mean in a particular workplace? This is hard to
specify, because part of being “exemplary” is that it should fit its context as well as
possible. In some cases this might mean that a normed multiple-choice test is
“exemplary”. In other cases it might mean that a portfolio of student work, or a recital
or exhibition or performance, combined with a face-to-face oral interview between
the student, and a panel of instructor-assessors, might be the best way of assessing the
student's learning, because it fits the student’s learning best.

What is “Exemplary Assessment”, then? Simply “horses for courses” — fitting
the best possible assessment in the best possible way with the specific circumstances
that apply to the instructional-learning situation being considered.

This is not THE explicit once-and-for-all comprehensively definitive answer. But
it is an effective indicative answer, a collection of ideas that help us talk about
possible ways of answering aspects of this question.

Obviously, logically, anything “exemplary” is an example that is so good it is
held up for admiration, as a model and moral example for others to follow.

Hence, considering this question, we are really looking for ways of distinguishing
goodness, or “quality” in assessment, and, simultaneously, identifying things that are
not so good. Incidentally, the idea of “exemplary assessment” does not appear overtly
in the research literature on assessment — not as far as I know. I would be delighted
to hear otherwise, if anyone can provide examples of books, chapters or articles that
state, explicitly, what makes assessment good, contrasted with what makes it bad —
broadly.

I am well aware of the large number of articles that say things like “high-stakes
testing is wicked”, and “all standardised test are evil”. I have also come across
suggestions that any kind of assessment is educationally abhorrent. I disagree with all
of these extreme views.

I think that some assessment is bad, for particular reasons, and other assessment is
good, for other reasons; and amongst the good examples, some kinds of assessment
are better than others. As in everything else, “quality” comes as varying spectrum,
from Extremely Poor Quality to Extremely High Quality. The task, right now, is to
try to identify features which, taken together, indicate high quality — good enough to
be held up as an outstandingly positive example — “exemplary”.

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Stating this very briefly, exemplary assessment is:

- valid;
- reliable;
- fair;
- transparent;
- flexible; and
- moderated, or calibrated, against other judgements.

Here, by “valid”, I mean the usual idea of “validity” that is used in discussing formal assessment (such as tests), but I want to broaden this to less formal approaches also. If assessment tasks are valid they match the curriculum: subject-matter and the instructional-methodology; the what, how, when and why of instruction.

The assessment matches the content (information, skills, concepts, processes) being taught. It also matches the method of instruction or teaching as well as the corresponding learning activities that occur in the classroom, laboratory, theatre, workshop, gymnasium, dancehall, playing-field, factory or studio, etc.). The assessment will also match the time allowed for the learning, and the sequencing of the instructional and learning activities. Finally, the assessment, importantly, matches the overall purpose of the learning situation.

For example, if the curriculum is mathematics, based on a traditional textbook-focused exercise-practising approach (which CAN be a very effective way of developing important mathematics skills), then it is “valid” to assess using practice-exercise materials, within the time-frame of a class-lesson (or longer, if students are reasonably sturdy — but see “flexibility”, later). It would NOT be valid to assess this approach using an extended (e.g. 3-week, out-of-school) problem-solving project or investigation.

Similarly, if the curriculum consists of real-life activities, then valid assessment of this would be some part of these real-life activities, or some close simulation of them.

By “reliable” I have in mind a generalised version of the usual idea of “reliability” as applied to formal assessment. In particular, if a test is given today, for example, and the same test (or an equivalent version of the test) is given tomorrow (or a week later, without students having further opportunity to practice and without further instruction that might alter their initial performance) the two test results should be close to each other.

Broadly speaking this means that reliable assessment is “trustable”. The results it gives for one student should be meaningfully relatable to results it gives for another student. The assessment is not capricious, or accidentally random. If a student can do a particular kind of project and show a particular level of achievement in the project, then a comparable level of achievement should be possible with a different project.

Here, broadening our idea of “repeated” assessment, we need to realise that individual interests vary. Billie may be surprisingly interested in the Mogul Empire of India, but bored to tears by the Aztecs, or vice versa. This difference in personal interest will obviously color Billie's achievement on two otherwise similar projects. That is simply human nature. Good assessment has to allow for it. Of course, if the assessment contributes to important decision-making, Billie should be aware of this, and not be swayed unduly by his or her personal likes and dislikes. But this relates to “transparency”, discussed later.
In particular, reliable assessment will yield the same results regardless of who
does the assessing. It is objective, not subjective. (Here, the assessor's likes and
dislikes are not allowed to color the judgments being made — the flip-side of the
students' likes and dislikes.)

Good assessment is “fair”. The tasks, or questions, or test items, are not harder
for some groups than for others, because part of the content being assessed is less
familiar to one group, or because experiences or processes involved in the assessment
are not part of the life and educational experiences of those being assessed.

Questions about fairness typically raise issues of social diversity, such as gender,
culture, age, and class.

If, for example, the subject is “Popular Music”, it may make a difference if our
class includes mature-age students whose ideas of "popular music" focus on Bing
Crosby, Frank Sinatra, Guy Lombardo and Mantovani, while others in the class think
“popular music” begins (and maybe ends) with Elvis Presley, while others think
anything older than two years, by definition, isn't "popular", although it may be
"classic" or "golden oldies".

Similarly "opera" means different things, depending on whether it is Peking
Opera, Balinese shadow puppets, The Who's Tommy, or Purcell's Dido and Aeneas.

In literacy assessment, a person whose life-reading consists of Sports pages and
big-rig truck manuals will suffer, perhaps unfairly, if the assessment material consists
of an extract from Charles Dickens, or an e e cummings poem.

But assessment will usually be fair if it is “valid”, because it will correspond
meaningfully and practically to what has been experienced during classes.

When good assessment is “transparent”, this means that those being assessed
know what is going to happen to them, they are familiar with the kind of assessment
activities, and content being used. They also understand how their work will be
graded, because the criteria for judging the assessment have been explicitly stated and
explained, with worked examples.

Similarly those being assessed know what the purposes of the assessment are, and
what the possible outcomes from the assessment, and the decisions that will follow
the assessment could be. If the assessment is an ordinary part of the give and take in a
school classroom, the students being assessed will feel at home with what happens
when they are assessed. If major decisions hinge on how well the students perform,
the students will know this, and will make sensible decisions about how much effort
they are willing or able to put into their assessment performance.

Flexibility of assessment is very important. Good assessment adjusts itself to suit
the particular needs of the students being assessed — the right course for the right
horse, and vice versa. Those who panic over tests are helped to find alternative ways
of sitting the test that will reduce their panic-levels. If the time-limit on an assessment
task is too harsh for some students, they may be allowed extra time. Students who
struggle with reading will be allowed to have the assessment presented to them orally,
and they will be allowed to respond orally, or be allowed other support (such as using
a wordprocessor or voice-recognition software) that will help them cope with the
assessment task at their own level of operating.
Importantly, as part of flexibility, those being assessed have clear, accountable processes of appeal if for any reason they feel aggrieved by the outcomes of their assessment.

Good assessment will be “variable” or “diverse in nature. It will NOT be arbitrarily and absolutely pre-determined by one specific assessment task, such as one solitary end-of-year exam (unless suitable flexibility, rights of appeal, and training for the assessment task, or other necessary factors mean that this is not an unrelentingly brutal do-or-die situation). Instead it will consist of several separate pieces of assessment, usually compiled across several weeks of time, or longer, with different activities occurring in different pieces.

Similarly, within a single test, project, or work-requirement, there will be variety in the question-type or tasks. A test that is only multiple-choice is clearly less “good” than a test that mixes multiple-choice with other forms of questions. Similarly a test of (so called) intelligence that relies on only complete-the-visual-matrix questions can hardly claim to be indicative of the known variability of intelligence, although such an item-specific test may give extremely valuable information about PART of a person's intelligence.

This is one aspect of the assessment being “moderated”. Another aspect is that teachers and instructors have scope to comment on, amend, appeal, or otherwise “moderate” whatever comes from student assessment, particularly when the assessment is imposed on teachers from outside institutions such as university examination boards, or State education authorities.

This allows personally (and professionally) informed “calibration” of otherwise impersonal assessment judgments. This can also occur, after state-wide testing, when students are being selected for university study, vocational training, or employment. Staff in universities, polytechnics, training institutions, and employers, naturally, may interview those students whose overall assessment ranking or test scores do not allow clear-cut decisions to be made, or those whose particular circumstances require careful individual judging.

One formal way of moderating specific assessment is to match it against more general forms of assessment. While this is often regarded as part of the worst-case high-stakes situations, matching subject-test scores against general academic ability scores is a sensible way of screening for anomalies, or unfairnesses, as well as checking on class groups, school groups, and other groups in the whole assessment pool, by co-relating or calibrating different kinds of assessment.

Put all of these attributes together in a particular piece of assessment, or as a collection of separate, different, mutually articulated assessment judgments, and the result should be — exemplary.

This piece of curriculum development may not, itself, be exemplary, being no more than an outline of views and arguments. But it is, I hope, clear and indicative as an answer to the question: What is exemplary assessment?

Incidentally, although this extended discussion of assessment may seem out of place in this Research Symposium, I will only suggest, briefly, that effective assessment practices are extremely valuable data-gathering tools, and hence have great potential in classroom-focused (and other) research.
Conclusion(s)?

Finally, let me summarise my sense of curriculum development as a form of research by presenting it as a form of problem solving. Consider Georg Polya’s familiar four-stage process of problem solving:

- Look;
- Plan;
- Do; and
- Check (Polya 1945).

How might these apply to curriculum development?

First, we begin by looking at our present context.

We consider our current situation, and our current underlying theories and guiding assumptions: where are we, what are we doing, how did we get here, and why are we doing these things?

More importantly we do this initial self-regarding looking in a problem-posing, or problematising way, actively seeking to expose difficulties, uncertainties, contradictions, ambiguities, unconsidered hidden assumptions.

What things are working well? What things are not working so well? How do we know that these things, whatever they are, are working well or not?

We reach a tentative end of this opening stage with a clearer sense of our immediate position, and its problems, and the theories that describe and explain this position.

Next we plan. Having explored our situation, and exposed likely problems, we cast around creatively, laterally, perhaps even randomly, and usually eclectically, seeking possible alternatives that might be trialed, any one of which might help move forwards to greater insight, fresh or renewed vision, improved practices. We are simultaneously devising new materials and new procedures.

Obviously the next step is to implement one or more of our tentatively offered alternatives. As we do so we monitor what happens.

The fourth Polya stage of Checking is simultaneously occurring all through all the other three stages, as well as featuring prominently as a tentatively final stage. How are things progressing? How far have we traveled? Have the potential solutions really solved anything, and, if so, what?

Teachers, of course, do this kind of thing often. But they are less often fully aware of this, as the familiarity of what they are doing, their confident, comfortable use of day-by-day routines, conceals the potentially inherent problem-posing and problem-solving nature of their professional routines.

By contrast, researchers do this kind of thing deliberately, actively trying to generate fresh questions to ask, and to investigate, hunting for answers.

My main point is that curriculum development, as an aspect of teaching, IS often a form of research, and deserves to be recognised as such. Equally, teachers, in their own small-scale day-by-day-routine way, are often researchers, and deserve to be recognised as such.

I have argued that curriculum development is a form of research. As such, it is one engaged in regularly by many teachers, without them realizing the research aspects of what they are doing. However teacher-researchers are potentially well
placed to contribute to the published body of research, and should do so. Several simple steps may assist them.

Critically evaluate the current circumstances:
• what curriculum is currently used?
• what are its strengths, and weaknesses?
• what are the current (and likely future) educational goals for this (or future) curriculum?
• what possible alternative curriculum exists, or could be devised, and what alternative instructional methodology might be used or developed?

Put the results of this problem-posing, critical analysis, and proposed problem solutions into academically supported written form. Circulate the draft for discussion among colleagues. Submit any revised form for possible publication in an appropriate professional education journal, for wider dissemination and discussion, and further critical evaluation and critically informed development.

That IS research! We ought not neglect or slight it.

References


Exploring constructivism(s): the gaps between philosophy, psychology, praxis and common sense(s).


ABSTRACT
Constructivism (plural or singular) may be popular, but is not always well understood. Significant differences exist between the way the term is used by mathematics educators, science educators, and others. So called 'radical' forms of constructivism are even less well understood. Yet do we, eventually, believe that we create what we know, or do we discover things which in some way already exist separately and objectively from us? How objective is knowledge? Does it help classroom practice to split these kinds of hairs? The research methodology, unavoidably, is conceptual, critical, cultural, discursive and philosophical.

PAPER
How I Do My Research
Let me declare my methodology at the outset. Self-funded, or unfunded, this project, like all my other research activities, uses three basic methods. I read. I think. And I argue. A fundamental research tool is my writing. Out of the struggle to find words for the ideas and experiences I am trying to grapple with comes some developing sense of insight, and the possibility that I can communicate some of this insight to others.

Sometimes I use a special kind of experiment, known also by the German name gedanken experimentieren, which translates (roughly) as 'thought experiment'. The English term is used extensively through Imre Lakatos's Proofs and Refutations: The Logic of Mathematical Discovery (1976 p 9, and elsewhere). Lakatos identifies such an approach as beginning with the Ancient Greeks who had a Greek word for it, deiknymi. Most of the early Greeks' speculative discussion of the nature of 'elements' and 'atoms' relied wholly on such thought experiments.

As I read, and think, I test my thinking by examining the consequences, when I make certain assumptions. Depending on the consequences that seem to follow, I am able to confirm or disconfirm my thinking. (Notice my unreconstructed Popperianism.)

We all use this methodology, in different ways, sometimes more formally, sometimes without being even aware that this is what we are doing. My methodology breaks no new ground. Probably the actual content or subject of my research breaks no new ground either. But I believe that I am making progress for myself. And I as I develop my thinking, testing it through my writing by seeking critical feedback from others, I believe that my work, unoriginal though it may be, may in turn help others develop also. So much, then, for methodology. I would, of course, with time or funds or interested colleagues (who were willing to contribute, for their part of collegiality, a
more explicitly experimental, descriptive measuring and evaluative approach), always be willing to have the content or focus of my 'research' examined within classrooms or laboratories. In the meantime, as I develop new teaching materials for my own use, I try the materials out on my own students, making further modifications in response to these trials.

**What I am Researching (Some of It …) — The (My) Background**

As my title indicates, I have recently been re-examining ideas about how children (students, people) 'learn', and what we might mean when we talk about 'learning', 'knowing' and 'knowledge'. I say 're-examine' because I first started investigating (in my read-think-argue way) these ideas when I was initially training to be a high school mathematics teacher, nearly twenty-five years ago, and later when I was doing Masters course work and lecturing in teacher education at the Burwood campus.

Back then it became clear to me that we 'learn' in a way that resembles the methods of discovery used by scientists (moments of insight embedded in a cyclic Popperian process of hypothesis formation, experimentation, and subsequent refinement and extension of hypotheses (e.g. Magee 1973): all of this is very similar to aspects of Polya-type mathematics problem solving). This 'learning' also resembles the unconscious (un-self-aware) learning of infants who are 'learning' to speak, walk, and become people. (Several articles discussed such a view of 'learning': Clements and Gough 1978, Gough 1982, Gough 1983, Gough 1984.)

At the time I was pulling together things I had first come across in courses on Education Psychology, my first-year undergraduate course Psychology 1 ('rats and stats'—a typical Monash approach of the day, showing up Melbourne University's stick-in-the-mud Freudianism), along with ideas of psycholinguistics, history and philosophy of science, history and philosophy of mathematics, process approaches to reading, spelling and writing, and the language-across-the-curriculum movement. Syncretic, and eclectic.

Constructivism had not been invented yet, as a term, at least not as far as I was aware. Piaget had just established (that is, his works, some from as early as the 1930s, recently translated into English were increasingly being popularised) a 'cognitive' and 'developmental' approach as an alternative to the then rampant American behaviourism, and already I was becoming critical of Piaget and looking for a theory of learning that was more closely embedded within the nature of a particular process or a particular subject area. Hints of such a theory could be discerned in Margaret Donaldson's *Children's Minds* (1978) and Margaret Boden's critical survey *Piaget* (1979). Ideas of information processing and artificial intelligence seemed to be especially helpful because they suggested a way of describing 'processes' of thinking, talking and acting.

The earlier work of Richard Skemp, subsequently revised, attempted to develop Piaget's ideas and apply them to an account of how mathematics was learned (*The Psychology of Learning Mathematics* 1971). This paralleled similar and even earlier attempts by Zoltan Dienes to develop some Piaget-like theory of concept development (e.g. *Building Up Mathematics* 1960).
My 1981 Master of Educational Studies project, titled 'Meaning Learning: Effective Teaching', attempted to discuss *meaning-making* (as I termed it) as a central 'learning' process in curriculum areas as diverse as reading, spelling, handwriting, art, music and mathematics. The British movement to find ways of connecting ideas about language processes (and language learning), led by researchers such as James Britton, Harold Rosen, and Douglas Barnes, allied in some ways with the British philosophers of education led by R.S. Peters, and paralleled by North American researchers and popularisers such as Paul Kohlers, Kenneth Goodman, Frank Smith and Donald Graves (whose process approach to writing was still very new), seemed to indicate a way ahead.

**Bringing Mathematics into the Picture**

But where did mathematics fit into such ideas? And what was mathematics, anyway? My earlier 1976 Master of Science thesis, 'The Mathematics of Some Logic Games', had discussed, amongst other things, the formalist-logician approaches of Hilbert and the disturbing limitations to logicism demonstrated by Gödel, and the 'learning-like' scientific inductive hypothesis-testing methods involved in playing *Queries 'N Theories*, a mathematico-language-logic game (drawing on Noam Chomsky's idea of formal grammars and the Grammarama Project of George A. Miller, e.g. 1957, 1967, which itself drew on the formalist logic-language systems of Emil Post during the 1920s — early versions of what later were known as Turing machines, and finally became actual computers!), developed by Layman E. Allen, the inventor of *Wff 'N Proof* (1962), working with Peter Kugel and Joan Ross. (Other papers attempted to discuss these issues and offer classroom applications and simulations: Gough 1978, anticipating the 1980s emphasis on the topic of problem solving, and Gough 1979.)

Floating around in all of this was the central 'learning' topic of 'concept development'. What, for instance, was a 'concept'? How did it develop? What role might a teacher have in attempting to help students develop 'concepts'? Skemp introduced the term 'schema' (its plural, if we accept the Greekness of the word, 'schemata'), rather than concept, and this opened at least three more connections which compound and extend the discussion. I had earlier come across 'schema' in Ernst Gombrich's brilliant discussion of pictorial schema (which in this setting were essentially visual patterns, cultural constructs, or 'conventions') in visual art: *Art and Illusion: A Study in the Psychology of Pictorial Representation* (1960) when I had been investigating the history of pictorial perspective in art, as one of my rather wide-ranging assignments carried out during my Dip. Ed. year when I was training to be a Secondary mathematics teacher. Amazingly (amazing for me), Gombrich used a Popperian kind of perceptual psychology, where concepts, that is what the brain believed and hence expected (or hypothesised) directed the experiments carried out by the eyes when looking around the world.

Not only was this exactly the theory offered by the psycholinguists (such as Goodman and Smith) to describe the process of reading (and writing, and other language forms), it was also the theory of oral language acquisition offered by other psycholinguists (such as Roger Brown, outlined by de Villiers and de Villiers 1979). Moreover, Gombrich pushed the idea of 'schema' or 'concept' further back in history, before Piaget, identifying F.C. Bartlett's work on memory (1932) as his source for the term.
Moreover, Gombrich's discussion ranged across other non-European cultures, as any investigation of perspective and alternative methods of representation must do. This brought in cross-cultural comparisons, and anthropological approaches, and, inevitably raised the **Sapir-Whorf Hypothesis** which I had first encountered in Postman and Weingartner's radical discussion *Teaching as a Subversive Activity* (1969). As with the theory about the reading process, and Gombrich's account of how we look at the world, we 'see' whatever we think we see through what we 'know'. That is, our sense of something we think of as the 'world' (which is in some sense outside us, yet also includes us as part of it) is only our personal (although usually socially-shared) 'world-view' as it is partially clumsily expressed within the language we use to discuss the world. Whether any kind of objectively describable world actually exists other than our language-refracted rather hypothetical and tentative model of such a possible world is a subtle philosophical topic.

Pretty radical. This comes close to the heart of Ludwig Wittgenstein's idea that language itself works like a kind of 'game', where rules, conventions and meanings are mutually negotiated as well as may be practically possible, by participating players, within particular contexts, always taking many things for granted, sometimes without being aware of what has been implicitly assumed or realising the logical consequences of such assumptions and conventions, knowing that any attempt to define everything turns into an infinite regress of definitions. The game-like nature of language, and hence of communication, and also of 'knowing', resembles the arbitrary game-like nature of a formalist-logicist view of mathematics.

Clearly I have been looking widely, and across a considerable period of time.

**Focussing on Constructivism and its Origins**

Later the term 'constructivism' began to be used. By then I was familiar with the expression 'cognitivism' as it was used by Robert B. Davis (1984), who I already knew as the pioneer of the Madison Project which I had discussed in my 1978 paper on scientific method as I saw it, (Popperian), being applied to mathematics making and learning (Lakatosian). Davis's own *Learning Mathematics: The Cognitive Science Approach to Mathematics Education* (1984) had barely appeared when a popularising teacher-directed account of a constructivist treatment of mathematics (and other subject areas) appeared in the *Frameworks* series prepared as official curriculum documents by the Victorian Ministry of Education (e.g. Cribb, et al. *The Mathematics Framework: P–10* 1988, chapter 3 'How Do We Learn? And How Do We Learn Mathematics?'). The *Frameworks* authors saw learning as an active constructive process of concept development which occurred in all subject areas, and in mathematics in particular. They even offered a concept-map-like diagram (p 21) showing concepts as objects like speech-balloons, each equipped with several hooks which could be linked with other speech-balloon-concepts—exactly the same kind of diagram given by that grand pioneer of thinking about thinking and learning Edward de Bono in *The Mechanism of Mind* (1969 p 232) in his subject-specific discussion of 'mathematical thinking', one of four different kinds of thinking discussed by de Bono in this book.

After *Frameworks* we have all been 'constructivists' ever since. Long live constructivism! But what does it mean? And what difference does it make?
Almost as soon as we hear someone give a sketch account of 'constructivism' we realise that of course we have always been constructivists, whether we used the term or not (like Moliere's character who was delighted to discover he had been speaking in prose all his life, despite the fact that he had never heard the word before). Trivially, because we each do our own learning (I certainly can't do any learning for you — and vice versa — remember the story of the boy who taught his dog to whistle? he taught the dog, but the dog didn't learn!), we are each in some way constructing 'meanings', 'facts', 'concepts' and 'skills' all the time that we learn. So what else is knew then, apart from using a new word?

Amazingly (amazingly for me), these constructivist ideas have been around an extremely long time, hidden in overlooked religio-philosophical treatises (as with Giambattista Vico's surprising account of a constructivist philosophy of knowledge) or concealed within the airier speculations of philosophers as far back as Plato and Aristotle and the Ionians. I am indebted to Judy Mousley for showing me this (1997). The great constructivist theorist Ernst von Glasersfeld has given several historical accounts also (e.g. 1989). Once we go that far back we need to be on our guard. Plato, in particular, reigns seemingly invincible in this era of philosophy. Yet Plato may not be right, if such a judgement is possible or sensible. A strong case can be mounted against his theory (or 'myth') of a higher 'Reality' of which our material world is but an illusion, a flawed and pale imitation (deceptive shadows cast on the walls of a dimly lit cave by some reality outside the cave of human material experience). For example, the Sophists and Ionian philosophers still have a lot to teach us about ordinary 'reality' and the incompleteness and relativity of 'knowledge', offering a valuable corrective to Plato (for example Robert M. Pirsig's challenging philosophical novel, *Zen and the Art of Motorcycle Maintenance: An Inquiry into Values*, 1974).

But, but, but, … what difference does it make? What does constructivism offer that you can't get anywhere else, such as John Sweller's helpful 'cognitive load' theory, which connects with earlier ideas of information processing and cognitivism (e.g. 1991)? Are we forced back to Piaget, sometimes identified as an early (comparatively early) constructivist? Perhaps even worse, as soon as we start looking for solid details about what constructivism either means, or does, we discover significant variation in how the term is used.

**Constructivism and Mathematics-Education — Helpful Technical Terms**

In mathematics education the researchers who identify themselves as 'constructivist' (of some kind, radical, social or other) present helpful terms (sometimes ugly neologisms, roughly coined new words and smashings together of existing word-parts) that describe what we might actually see (or hear) students doing that indicates that they are in some sense 'constructing'. For example, von Glasersfeld offers the term 'subitising' (1982) which is the ability to ascribe a number (a concept or schema, or possibly a numeral, which is a representation of the number-concept expressed orally or as a written word or a written symbol, a digit or collection of digits or similar symbolic coding) instantaneously (or as quickly as mental-processing response-time experiments can establish) to a pattern of objects. In effect this is a kind of domino-reading or sight-word 'flash-card' ability to see a card with a collection of dots and instantly say how many dots have been seen. Glenn Doman (often associated
with the infamous unscientific brain-hemisphere psycho-motor developmental theories of Carl Delacatto) used this ability to subitise as the basis for his book designed to teach babies mathematics (I would appreciate any help I could get here, as I have no reference for this book, and its accompanying kit of flashcards: it is a companion volume to Doman's better known *Teach Your Baby to Read* 1963).

Interestingly, some forms of subitising seem to have a biological or genetic basis. According to Edward MacNeal, the researcher Otto Koehler (1889-1974) was able to show that species of birds were able to distinguish quantitative differences (such as marks on a container, or a successive number of events before a known consequence occurred). Pigeons can 'count' to five. Ravens and parrots can 'count' to seven. Koehler described this as 'unnamed' or 'prelinguistic' counting (MacNeal 1994 p 91). It would be interesting to know how such counting operates in experimental situations where animals are involved in language training (e.g. Linden, 1974, 1993). Such a biological basis for mathematics has been recently argued by Stanislaus Dehaene (1997) who claims to have located the position in the brain that is active during calculation with numbers, and other researchers such as George Lakoff and Rafael Nunez.

Steffe and Cobbe (1988), colleagues of von Glasersfeld, speak of 'unitising', which is the conceptual act of taking as a whole something which up until then has been handled as a collection of discrete unitary elements. A related constructivist tool for constructing is 'disembedding', or being able to dissociate sub-units from a composite unit while still recognising the unity of the larger whole. This clearly links with George Miller's pioneering discussion of 'chunking' as the cognitive process by which we are able to overcome the limited thinking-space of about seven 'spaces', plus or minus two (for an average adult), in short-term memory (1956, and Smith 1975, ch. 2). The term 'chunking' is apparently due to Herbert Simon (1974).

This also links with 'concept development', the collecting up of experiences and abstracting of a new concept sketched by Richard Skemp (and presumably many others before him). Skemp describes the way infants learn to abstract the concept of the color 'red' from many various instances of objects that exhibit 'redness', in association with information and feedback from adults and other color-experts interacting with the infants (1971 pp 25-26). Skemp remarks that a 'schema [or mental construct, or concept] has two main functions. It integrates existing knowledge, and it is a mental tool for the acquisition of new knowledge' (p 39). Obviously! The more we learn, the more we are able to learn. Does such analysis and introduction of supposedly explanatory terms really take us much further than common sense? And, beyond that, what are the limits of common sense, and can it sometimes mislead us?

Some researchers have investigated the process of concept formation by defining a new term 'encapsulation', the forming of a conceptual entity from a developing dynamic process (e.g. Dubinsky, 1991). Put more simply, we form ideas about objects and different ways we can use them, according to the things we do with the objects. Concept formation is then seen to be the encapsulation (or putting together) of the cognitive representation of a mathematical operation in combination with some corresponding procedure, such as a routinised manipulation of objects. With such an approach, the process of counting (including pointing at objects and uttering the sequence of oral numeral words) is encapsulated as the concept of 'number'. That is,
'number' is formed as an idea from combining the way we represent counting orally with the active processes involved in doing counting with objects. Repeated counting is encapsulated as addition. That is, addition is constructed as an idea built out of the way we represent successive counting of several groups of objects, combined with different active processes, such as counting all the objects after combining them, or counting on the next group of objects from where we have reached after counting the first group of objects (Gray and Tall 1994 pp 139-140). This 'encapsulation' resembles the 'curtailment of thinking', or the intuitive grasping of a whole sequence or collection of steps and ideas, described by Vadim Krutetskii (1976 p 45).

Gray and Tall also use the term 'proceptual thinking' to describe the combination of conceptual thinking and procedural thinking (which Skemp might describe as 'relational' and 'instrumental', respectively: 1976) including the meaningful use of known facts and procedures to solve problems. Discussing children learning to count, they distinguish this from children who are 'procedural counters' and depend on being able to physically manipulate objects as they carry out a counting procedure. These ideas are described in Pearn (1996 p 127). Many other researchers make this natural distinction between conceptual work and procedural work, linked also with representational work.

Gray and Tall (1994 pp 120, 137) include many mathematical concepts in their general discussion of their constructivist term 'procept'. … we consider the duality between process and concept in mathematics, in particular, using the same symbolism to represent both a process (such as the addition of two numbers $3 + 2$) and the product of that process (the sum $3 + 2$). The ambiguity of notation allows the successful thinker the flexibility in thought to move between the process to carry out a mathematical task and the concept to be mentally manipulated as part of a wider mental schema. Symbolism that inherently represents the amalgam of process/concept we call a 'procept'. … the successful mathematical thinker uses a mental structure that is manifest in the ability to think proceptually …

The less able are doing a more difficult form of mathematics, which eventually causes a divergence in performance between them and their more able peers. (Gray and Tall 1994 p 116.)

Gray and Tall also use the term 'encapsulation' for the mental action of grasping or forming 'a (static) conceptual entity [or 'cognitive object', or schema or concept] from a (dynamic) process', noting that other writers use terms such as 'entification' or 'reification' (1994 p 119). Does it matter that some researchers attempt hair-splitting distinctions in their technical definitions? Or can we attempt to make progress by recognising blurry overlap in concepts and methods, and settle on nice sounding sensible-seeming words that do a good enough job?

It may be noted that Gray and Tall actually use the term 'process' in a loose way, allowing for the possibility that some processes can be carried out in several different ways, unlike mechanised 'algorithms' or 'procedures' which always follow the same fixed rules, or standardised steps of thinking or calculation. The ideas and processes that are being learned at one level of understanding become encapsulated into a new cognitive entity. This means that whole clusters of ideas and performance can be treated as a new coherent single unit, which can act as a building block for further concepts and processes at a higher level of thinking. This encapsulated cluster of parts
now functions as one step in a higher process, **internalised** and **automated**. Such internalising and automating is a key feature in constructivist theory, as it has always been in common sense approaches to mathematics teaching and learning. Students find it difficult to progress far in mathematics without 'memorising' or 'learning by heart' their multiplication tables and a wide collection of number facts and concepts (for example, not just knowing that \(3 \times 4 = 12\), but that \(3 \times 40 = 120\), \(3 \times 4\) million = 12 million, \(3 \times 40\)¢ = $1.40, and so on).

Connections between particular ways of representing a concept (spoken words, written words, written symbols, diagrams, and manipulative objects), combined with the techniques or processes for working with this concept and its related representations, lead to the internalisation of the concept and automation of the process. Practice with showing, doing, and talking, leads to some kind of comprehension (up to a point) and the development of fluent skill. This, in turn, when internalised, becomes the basis for practice with new materials, new topics and concepts, and consequent new internalisation and automation. James Hiebert emphasises this when he notes that recent recommendations to decrease the emphasis on common drill-and-practice activities may prompt us to reconsider the way that such routine procedures may valuably contribute to the development of meaningful and useful mathematical knowledge. In particular he identifies the potential, within drill-and-practice, to develop the cognitive processes of 'atomisation' and 'reflection'. The goal of the former is merely efficient execution of procedures, and of the latter is a broader understanding, and the recognition of patterns and meanings (1990 p 39).

Clearly, for Hiebert, drill-and-practice, within a reflective context, increases efficiency and understanding. At this point it is worth mentioning another constructivist term **metacognition** — becoming self-aware, developing the ability to reflect on what is being done or what is being learned, the ability to think about ('meta'-) thinking ('cognition'). Of course this is important: common sense tell us so. Is this new term (Greek smashed with Latin) merely jargon to frighten parents?

How do constructivist researchers discover what goes on in children's minds, and hence find a need for these interesting new explanatory or descriptive terms? They use **clinical interviews** and close observation, in the same way the Piaget pioneered, examining the way students respond to different tasks, and analysing what the students say as well as what the students do. Teachers use clinical interviews, in the same way that they use 'miscue analysis' as they listen to learners struggling to read aloud, whenever they respond in a diagnostic interventional way to their students' ordinary classroom activities. We could add to this some of the related techniques of so called 'discourse analysis' that attempts to identify important features of who is talking, who has authority, who is listening, what is stated, what is implied, and so on, in any oral or written exchange between a group of people. But this, too, largely, is a matter of common sense.

**Constructivism Across the Curriculum? Or Language?**

Perhaps oddly, despite the first enthusiasm for the *Frameworks* approach to an overall constructivist view of learning in all curriculum areas, there has not, as far as I am aware, been a move to develop 'constructivism across the curriculum'. Perhaps this is because the earlier, comparable project to develop ideas of 'language across the
curriculum' tended to fall by the wayside, except where it resulted in enthusiasm for 'integrated' approaches to learning. Those who most persuasively argued for 'language across the curriculum' (such as a Britton, Rosen and Barnes, or in Australia, Brian Cambourne), tended to be people who were clearly only from a 'language' background, and they were largely unheard by the subject specialists of other curriculum areas.

Moreover, the so called 'process' approach, which simultaneously sprang from the results of language-oriented psycholinguistic research into children learning to speak, read and write, tended to shift the rhetoric from 'language' to 'process'. What that meant in practice was always difficult to pin down. It became popular to suggest that students, at all levels, should behave like the specialist adults, such as historians, biologists, geographers, mathematicians, artists, and physicists, and learn to use the adult-specialist processes (such as problem solving, carrying out laboratory experiments, writing for publication, and public performance). For a while 'process' was offered as the focus for all curriculum areas, particularly as the process was considered to be manageable and stable in an era of information explosion, when it was impossible even for trained adults to try to keep up with an explosion in content. Students, for example, no longer learned about history or geography, they learned how to do history or geography.

If we are now starting to re-set a practical balance between 'process' and 'content' we may be recognising that you can't use a process without having some substantial content to make sense of the meanings in the process. Moreover, despite the information explosion, we can see that there are some basic foundation content ideas which need to be established. For example, you need to know some mathematics (content) in order to be able to do some mathematics problem solving (process). That is, we can't have a process (noun) without something (i.e. content) to process (verb): this was argued by John Biggs as early as 1974. Of course the conceptual separation of process and content is only hypothetical, anyway.

Finally, without the necessary development of fully re-worked curriculum documents for all other subject areas, all that the 'language across the curriculum' proponents could offer were anthology-like snippets (a bit of discussion and a few examples and some children's talk dealing with, say, mathematics, a similar bit for history, and so on). The rest depended on the experts in the other subject areas picking up the ideas and writing the necessary 'language across mathematics' or 'language across social science' (and so on) resource books and curriculum materials. However this did not happen, apart from a slight shift to ensure that, in all subject areas, students were encouraged to talk about what they were learning, student-learning journals or diaries were sometimes introduced experimentally, and some renewed emphasis was given to working with different genres of writing in other subject areas, as we see in Victoria with the 'project'-like Investigation CATs at year 12-level.

**Constructivism and Science Education — Another Country?**

It should be stressed, however, that as soon as we shift from mathematics education research into students' learning, with its own flavour of 'constructivism', and move across into a seemingly similar curriculum area, we find that the term 'constructivism' refers to quite different things. In the field of science education discussion of constructivism seems to be less concerned with trying to identify or describe
important learning processes (that can then be generalised to help teachers begin to understand difficulties involved in trying to teach other parts of the curriculum), and is more concerned with the idea of "conceptual change". Theories of conceptual change attempt to explain, for example, how a student can shift from a naive Aristotelian view of moving objects, where the presence of friction means that a constant force is needed to maintain a moving object's velocity, to a Newtonian view of objects remaining in a state of rest or uniform motion unless acted upon by an external force (and later, to an Einsteinian relativistic view of space-time and mass-energy, in which the Newtonian view is simply a first-order approximation) (White and Gunstone 1989 pp 578-579).

Moreover several critics have argued that, as a movement recently promoted in science education, constructivism has rapidly become hopelessly broad and vague, weakens any useful distinctions between ideas of existing scientific knowledge and 'children's alternative frameworks' (such as naive Aristotelian friction-based particle dynamics), and undermines essential critical features of scientific method: for example, Solomon 1994, and Osborne 1996. One essential point here is that, despite being partly right in their alternatives, children's alternative frameworks can and should be criticised. From the criticism we develop less criticisable, more 'scientific', better frameworks. Discussing science education (for which we may read 'mathematics education') Osborne cites Hodson (1990) who distinguishes three dimensions: learning science, learning to do science, and learning about science (p 55). Constructivist theories tend to gloss over such distinctions, ignoring differences between the focuses of learning, doing and reflecting — indeed, the nature of knowing and knowledge.

It should be noted, that, unlike in science, children working with mathematics tend to have no alternative frameworks at all, certainly nothing that corresponds, for example, to a naive view that the world is flat, the sun moves around the earth, offspring are likely to inherit the skills of their parents, and friction-effects show the right way to think about objects 'naturally' moving — that is, if an object is moving, something must be pushing it, a view that was perfectly obvious to Aristotle, and took the minds of Galileo and Newton to overturn conceptually. Perhaps the only comparable naive-mathematics alternative view is the mug-gambler's theory that if we are tossing coins and we have seen 1000 Heads in a row, it stands to reason that we should get a Tail pretty darn soon, if not in fact the next time ( — what's wrong with that dad-blasted coin, anyway? I am reminded of the classic scene of coin-tossing in Tom Stoppard’s revisioning of Hamlet, Rosencrantz and Gildenstern).

Generally students tend not to form alternative views about mathematics, except on a small scale. For example, one such alternative view can be summarised as the 'rule': if in doubt, add. Another 'alternative rule' is: when subtracting, take the smaller digit from the larger, regardless of where the digits occur. These have been more usefully described as 'default' options or resistant 'bugs' in students' concept formation or cognitive processing (Davis 1984 pp 46-47, 43-44). The information processing or artificial intelligence metaphor behind these terms should be noted — Davis is a constructivist, but also a cognitivist, and is well aware of still other theories. Such 'default' expectations, and 'bugs' tend to arise when a student is not challenged enough, or is given practice tasks that are too simple, or that fail to include enough different operations and possible kinds of tasks. The constructivist solution is to demonstrate as
clearly as possible the actual consequences of the students' faulty thinking, to 'torpedo' the 'bug', to work through a step-by-step comparison of the faulty process and the correct process.

Robert B. Davis uses the expression "torpedoing" — asking an alternative question which corresponds to the [wrong] answer the student has actually given. Usually this prompts self-correction of the first question, and then a correct answer to the second question, and thoughtful clarification of confusable but related concepts: (Davis 1966 p 2; cited in Dawson 1969 pp. 174, 220, 221-222).

It may be noted, also, that some students' alternative views in mathematics consist of no more than a different way of handling a task, such as adding up a column of figures starting with the left-most column, rather than the right-most, and later adjusting backwards if necessary. Such 'alternatives' are actually 'informal strategies' devised by the students as a constructive, intuitive and creative response to explicit instruction, student observation, non-teacher demonstration, and loosely supervised practice. These informal strategies are often the methods that students carry away from school and use for the rest of their lives. Or these strategies may develop outside of formal school instruction — 'street mathematics', sometimes also reflecting interesting cultural differences where the formal school culture, essentially that of Western Europe, is seriously different from the local culture. As an example many adults show diverse ways of mentally calculating with time, methods that were never taught in school, but which are effective and robust, in that they continue to be used successfully for years, without need for modification. Other informal strategies spontaneously arise in response to everyday experiences with money, a major non-school focus for a great deal of mathematical thinking.

Interestingly, as far as I can tell from my own limited reading of science education discussions of constructivism, none of the mathematics education technical terms have been picked up, in particular 'encapsulation', 'unitising' (which is essentially the same thing?), 'disembedding' (whatever happened to 'embedding?'), 'procept' and so on. Other, broader terms such as 'metacognition' have crept into the formal vocabulary of researchers in almost all curriculum areas.

Another large difference between the mathematics flavour of constructivism and the science education flavour is that leading mathematics education theorists such as von Glasersfeld have argued for what he calls 'radical constructivism' which makes no necessary assumptions about the external objective reality of any of the mathematics that is being taught or learned. This 'radical' view stands in opposition to Platonist views of mathematics (and other kinds of knowledge) as exemplifying some transcendental 'reality', which exists 'out there', which creative mathematics investigate, like explorers attempting to chart unknown territory. The 'territory' exists, and the explorers are simply recording what they observe as they move around. For von Glasersfeld, and for the Vygotskian social constructivists, this is quite unacceptable. Mathematics, by their account, exists only as much as any other body of knowledge exists, in that it is made by humans and established by socially negotiated conventions or agreement.

So called social constructivists have adopted a version of the learning theories of the Soviet researcher Lev Vygotsky, often touted as an alternative to Piaget, who always
emphasised the individuality of the organism doing the learning, and tended to emphasise the importance of personal experience rather than the development of shared language. Vygotsky naturally saw the social collective as the focus of what was done and known (or else Stalin would have had a few sharp words to say to him — in those days political correctness was deadly serious), and discussed the way language functioned through the process of group experience, negotiation and consequent individual (collectively guided) concept development.

A philosopher such as Imré Lakatos straddles these ideas with his scrupulous account of the slow development of socially negotiated mathematical concepts, defining, testing definitions, proposing counter-examples, modifying definitions and theorems to take account of counter-example 'monsters'. For Lakatos mathematics exists as a human construction, known incompletely and fallibly (in a Popperian sense, namely, that tentatively held hypotheses can be disconfirmed by testing against examples and logical consequences). Moreover, mathematics is constantly in touch with some shared sense of an objective external world, where graphs are drawn, cardboard models of objects and 'monster'-counter-examples can be made, and the boundaries of understanding of humanly-created assumptions and definitions can be tested, experimentally, or at least as experimentally as mathematics can manage.

This is often misunderstood. Up until the mid-Nineteenth century the common view was that mathematics was different from fallible, correctible science. Mathematics was concerned with truths which did not depend on experiment. There was an absoluteness to mathematics which separated it, philosophically, from all other forms of knowledge. After all, $2 + 3 = 5$, for example, was held to be incontrovertible — even Martians and angels would accept this fact as 'true'. Euclidean geometry, to take another example, was simply a mathematical expression of the absolutely true properties of geometric space. Nice theory.

Along came the theories of non-Euclidean geometry, including the Einsteinian account of a space-time continuum whose practical non-Euclidean nature is used even when we program computers to assist with global-position calculations that help jumbo jets navigate — we don't have to go far in the universe to find that Euclidean mathematics fails to do the job well enough, however good it may be as a first approximation for building houses and bridges. Along came the paradoxes of set theory, and the challenge of Gödel's theorem (paradoxically, that there exist with the theory of ordinary arithmetic, statements which are true yet which can not be proved). The result was a retreat to an even more rarefied view of mathematics as a kind of formal and utterly arbitrary game that has no necessary relation to any kind of everyday life reality at all, except when we are doing business mathematics or 'applied mathematics', in which case the connections between the absolute ideal world of mathematics and the gritty real world is no more than a puzzling coincidence.

However mathematics has always been embedded in logical reasoning and has always tried to use definitions that fit with common sense experience. Repeatedly, when so called 'pure mathematicians' established some pretty result within their arbitrary deductive game, some other mathematician found a way of applying the otherwise idle speculation to a real world situation. This has always been the nature of mathematics and its connection with 'reality'. It is also the nature of the way students learn mathematics, fitting it against their everyday experience, and sometimes
extending their insight into such experience as a result of their new mathematical insight. Mathematics is a game, and often formal, yet probably never arbitrary.

This relation between the theoretical 'unworldliness' or otherwise of mathematics, also, is a key difference with science education ideas of constructivism. For physicists, biologists, geologists and others, in order to have anything on which to build research there needs to be a shared assumption that some kind of objective external real world (of bricks and trees, and atoms, and quarks) does exist in some reliable, commonly understood way. Scientists are hardly Platonists, and are unlikely to be much interested in the more rarefied interpretation of von Glasersfeld that, superficially, looks as though it denies the existence of anything except the individual knower — a philosophical stance known as 'solipsism', and not very helpful if you want to do anything.

However von Glasersfeld's seeming solipsism is more a caution against relying too much on the objective 'truth' of the posited 'real world'. The caution is sensible, even in hard-nosed science. What, for example, objective status can be ascribed to the concept of 'energy'? Or 'force'? Or 'space'? Or 'species'? Or (at a level of molecular self-replication) 'life'? These are arguably human constructs, constructed to make sense of some forms of socially negotiated observations of something which we might then suggest reflects some aspect of what, in an everyday common sense way, we take for granted to be the 'real' world. How 'real' is it, if the solid table against which we bruise our toe when we kick it (as Samuel Johnson attempted to dispose of the idealist theories of Bishop Berkeley), consists of Einsteinian warps in a space-time multi-dimensional field, or consists of 'space' between minute whirling quantum packets of mass-like energy or energy-manifesting mass, or superstrings of some mystical kind, or …?

At this point we might realise that we have run head on into the slippery boundaries or limits of just what can be captured in language, and the difficulties of using language to communicate. The challenging ideas of Ludwig Wittgenstein still tantalise some researchers (such as me) who try to grapple with the ideas of mathematics philosophy and the nature of knowing. It seems, however, that some science education researchers who discuss constructivism take the world of objects for granted, and equally take for granted the language they use to work and talk about their common sense world. This is understandable, but short-sighted, except that we don't need to know much about any of this to be able to function pretty well in the classroom — do we?

What About 'Constructivist Teaching'?

It should be clear by now that if constructivism, of different sorts, is about anything, it is a way of trying to describe what happens when people learn. The simple fact is that, regardless of how we may try to teach people, their attempt to learn will be describable in some way through a metaphor or theory of constructivism (and there are alternative metaphors which have not been entirely repudiated: for example, in an age of increasingly good experimental results in neuroscience, the seemingly discredited theory of behaviourism is far from dead!). Teachers who use discovery methods, Piagetian experiences, problem solving and contextually embedded immersion, chalk-and-talk, or even memorise-and-drill, and also those great teachers
of our television age (such as David Attenborough, Carl Sagan, Jonathan Miller and his namesake Julius Sumner Miller), all using vastly different methods, succeed (and, whether relying on rote, first-hand experience, or merely seeing and hearing, they all are capable of succeeding!) in getting their students to learn — this learning can be described as a 'construction'.

Logically, constructivism, which is a descriptive theory of learning, has no necessary implications for teaching. Some teachers fail to grasp this logic, and attempt to devise constructivist teaching situations. The result is little more than an attempt to combine a weak form of guided discovery learning with a step-by-step task analysis, working on the assumption that if students are going to 'construct' and the things they are constructing come in identifiable bits ('concepts', 'facts', 'skills', 'experiences') then we will help them do their learning-construction if we structure their potential-learning experiences in small building-block steps. Nice idea. But, logically, it is no more likely to result in constructivist learning than any other form of teaching such as tell-and-drill.

As a result, living as we do in an age of continual curriculum upheaval, experimentation and attempted change, it should be stressed that the changes that have recently occurred, and are continuing to occur in mathematics and science education (and other curriculum areas) are not necessarily due to the rise and acceptance of constructivist theories. Rather, these changes have occurred concurrently with the development of constructivism. While there may have been some mutual exchange and benefit between the constructivist theorists and the curriculum innovators (serendipity is a wonderful thing), it could be argued that the curriculum innovations would have occurred anyway, even if constructivism had never been invented.

In mathematics education, for example, such powerful factors as the rise of pocket calculators, graphic calculators, computers and mathematics software, along with the resolve to focus on problem solving (declared as the top priority for the 1980s by the National Council of Teachers of Mathematics, and adopted globally), along with the international rebellion against over-use of teacher-centred formalised normed testing and examination-dominated curricula, have resulted in great changes. We should also never forget the crisis forced by the Cold War and the adoption of the so called 'New Maths'. Similar factors have been at work in science education. The theories of learning that have washed over and through these curriculum upheavals have themselves had only small impact on the actual content of curriculum or the methods of curriculum development (except, as an extreme example, when some teachers decided to use 'programmed learning' — nowadays this has developed into far more flexible Computer-Assisted Learning).

As early as 1967, at a time when Cuisenaire was being quietly dropped in Victoria, the Association of Teachers of Mathematics, in Britain, discussing primary levels of mathematics curriculum, declared that (please excuse the naively sexist terms), Mathematics is the creation of human minds. ... Because mathematics is made by men and exists only in their minds, it must be made or re-made in the mind of each person who learns it. In this sense mathematics can only be learnt by being created ... We believe, then, that teaching which tries to simplify learning
by emphasising the mastery of small isolated steps does not help children, but
puts barriers in their way. (A.T.M. 1967 pp 1-3).
The discussion then moved on to a vision of teacher as facilitator in a child-centred
process of learning, embedded in a social context — a nutshell anticipation of almost
everything that would be claimed more than a decade later by constructivists,
Vygotskians, and others. The more things change...

Concluding...?
Having said all of this, the idea of 'constructing' remains almost totally theoretical or
notional. Where, after all, is this 'constructing' supposed to occur? In the student's
brain. And what kind of constructions exist, as far as we know, in the brain? Synapse
connections, that is, a kind of increased electrical nerve-cabling between certain
collections of brain cells, apparently due to some brain-response and activity based on
experience, mediated through the senses, in the 'real world'. And where are the
constructivists who have anything to say about synapses, neurons, or the functions of
the brain? And what about the problem of consciousness or human self-awareness?
Where are the synapses that handle that?

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Notes and Activities for the Presentation of the Symposium Paper: Exploring constructivism(s): the gaps between philosophy, psychology, praxis and common sense(s).

Summary:
Socio-genetic constructivism rules! — Is That OK? — Radical!
Or:
Wittgenstein 1, Plato nil.

First, write down the colors of the rainbow.

Next, listen to the following short verse:
The Moving Finger writes; and having writ,
Moves on: nor all they Piety nor wit
Shall lure it back to cancel half a line,
Nor all thy tears wash out a word of it.

from The Ruba’iyat of Omar Khayam (translated by Edward Fitgerald 1809-1883).

Now, what mental image, if any, did you form as you heard these words? Does it alter or challenge your image if I remind you that the original author (whose words you heard in translation) was writing in Arabic, where the pen moves from right to left?

(Does it matter if the first line reminded you only of Spike Milligan's parody:
The Moving Finger writes, and having writ,
Moves on — to write another little bit.)

Will it matter, in one hundred year's time if the common understanding of the word 'write' or the role of the moving finger, has nothing to do with pens — even now, for many of us, 'writing' really means keyboard drafting!

Here is the first point: All knowledge is constructed convention.

(Let me slightly amend that: almost all knowledge. Some knowledge can be regarded as genetically pre-determined or structured, rather than conventionally constructed. I may say something about this later.)

You can know the name of [a] bird in all the languages of the world, but when you're finished, you'll know absolutely nothing whatever about the bird... I learned very early the difference between knowing the name of something and knowing something. All you'll know about is the patterns of meanings and language-use which these bird names show—you know about the namer, not the named!
Here is a second point. All knowledge is convention, or even common sense. But we need to be aware of the question 'Whose convention? Whose common sense?'

Let me give an example. If we talk about fish, will we be satisfied to use the example of the Polynesian fishermen (reported by Malinowski, in James Britton *Language and Learning*, Penguin, 1970 p 24) who have three words for fish: these are equivalent to fish-I-eat, fish-that-eat-me, and other-fish, or the-swimming-thing.

Try these simple tasks:
- Round 2.51 to the nearest whole number.
- Next, round 45 cents to the nearest whole dollar.
What am I getting at here?
While rounding is a straight-forward process, it may expose some of our personal and cultural views about the concept of 'zero'.

Consider the following exchange, developed from MacNeal (p 128):

Q: Does the equation have a number of solutions?
A1: No, only one solution.
A2: No, no solution.

The first answer implies that 'one' is not a number: when we have a number of solutions we necessarily have more than one solution. The second answer similarly implies that 'zero' is not a number.

At this point we are the mercy of the Greek view that 'nothing' does not really signify anything, and that 'one' is not a number, but is a unit by which we can measure other numbers larger than one. By contrast, the Hindu view accepts nothingness as a state of being which can legitimately be used in sensible discussion.

Incidentally, the word 'three', in many Indo-European languages, relates to a Sanskrit root which can be seen in the Latin stem 'trans' which means through or beyond, or many. Hence the old story of people who counted 'one, two, many'.

Here is another short task: write down a definition of the term 'spectrum'.

We see the world through our accepted conventions, often without being aware of actually using conventions. Rather, we think we see what actually is. We think that what we see actually exists. Consider the word 'image' or 'IMAGE' —

**IMAGE**

Do we see letters, or only the shadow-outline of letters? (Adapted from a similar example by R.L Gregory, cited by Gombrich, in Gregory and Gombrich, 1973).

Only when we try to use a different world-view can we realise the conventional nature of much of our thinking.

MacNeal (pp 137-139 and 202-203) describes Hopi ideas of time. We speak of a period of three days. Time can be sliced. Hopi speak of time that is unsliceable and can only be experienced. We discuss a trip that takes three days. The Hopi talk about
a trip that finishes at the end of the third day. We say that twenty days is longer than ten days. The Hopi say that the twentieth day comes after the tenth day.

Now, coming back to the rainbow and spectrum questions, write down why you have a finite list of colors as the answer for the first question when a spectrum is essentially a continuum?

Knowledge is something that exists inside people's heads, stored as neural circuits, electro-chemically strengthened networks or connected collections of brain cells known as neurons.

Knowledge can be derived from experience, but can also, in certain forms, be permanently 'wired' into an organism's brain at birth. It appears that part of our ability to respond to the appearance of eyes in something which appears to be a face may actually be biologically built-in at birth, rather than anything we learn, that is, personally construct from experience. Other sensory responses to our ordinary environment, such as the ability to detect apparent depth (that is, plunging vertical distance ahead of us, or at our feet), may also be genetically predetermined, or 'hard-wired' into our brain's circuitry at birth. Awareness (albeit unreflective, not within active consciousness) that an object is rapidly approaching our head, in response to which we rapidly blink our eyes shut, flinch or wince or attempt to duck for cover—this too seems to be present from birth, rather than being learned by trial and error after being hit a few times by rapidly approaching pillows, and other air-born missiles directed towards our heads by malign circumstances beyond our control.

Intuition is what we think before we know.

Knowledge is represented outside of people's heads by means of writing, diagrams, symbols and other forms of archival representation (CD-ROM, video tape, computer memory, and so on).

Knowledge is a 'convention', negotiated by knowers, communicated approximately by language, symbols, signs, physical performance.

Learning is a process of negotiation between initial-knower and would-be knower.

A great deal depends on what one person means and knows, on what the other person knows and thinks is meant, on the present context and purposes (possibly differently understood).

We make and control our own meanings. Nonetheless it is possible for us to make mistakes. We may fail to recognise what are logical consequences of things we think we are saying. We may say the exact opposite of what we really mean, and our listeners may actually hear us say exactly what we mean to say, even though we say the opposite.

Consider this more technically demanding example:
— Explain what basic mistake has been made in the following textbook passage:
  'As the temperature of the filament [of thin tungsten] increases, its resistance increases due to an increase in tungsten's resistivity' (Lofts, G., O'Keefe, D.,

The practical point is that how we think of the subject matter we are trying to teach, the bridges we are trying to build, and the territories that are connected by the bridge, effects how we teach it, how we react the students we interact with, and the way we try to negotiate a mutually acceptable map of what we are doing.

**References**


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**A Collection of Questions and Activities for the Symposium Paper:**

*Exploring constructivism(s): the gaps between philosophy, psychology, praxis and common sense(s).*

1. Explain the reason for the English language dislike of using split infinitives, to simply show the role of 'convention' in language development and use.

2. Match each of the following food combinations with one of the following sources or contexts.
   A Empty a can of sardines into a bowl of tomato soup.
   B Use cod liver oil as a condiment on roast beef and vegetables
   C Vanilla icecream sprinkled with potato crisps
   D Chicken casserole with dark (bitter) chocolate sauce
   E Applying a sauce whose main ingredient is fish guts to almost all foods eaten
   F Serve well-fried bacon with pancakes and liberal amounts of maple syrup

   (i) One of Bob Hawke's favourite dishes
   (ii) Fred Hoyle *The Black Cloud* (science fiction novel)
   (iii) a favourite Aztec dish
   (iv) Margaret Craven *I Heard the Owl Call My Name* (novel)
   (v) hearty lumberjack food
   (vi) typical cuisine of Ancient Rome

3. Explain why black is not a color. Explain why white is not a color. In terms of color concepts, what would you call silver? Why is Homer's sea 'wine-dark'?

4. For each of these two photos (one shows a man holding a lottery ball towards the camera nearly in line with his face, the ball seems much larger than the man's mouth and nose: and one shows a street scene with skyscraper where the buildings seem to tip away from the viewer), identify the particular camera lens used to achieve this effect.
   A Fish-eye lens
   B Wide-angle lens
   C Normal lens
   D Deep-focus lens
E. Multi-facet lens
5. Explain what basic mistake has been made in the following textbook passage:


6. A spherical steel ball of mass 500 gram is released from the top of a long inclined plane, sloping at an angle of 30 degrees to the horizontal. Rolling down the plane, having started from rest, how fast is the ball rolling after 10 seconds?

   Remember that Newton's Second Law (the Law of Inertia) states that $F = ma$ (the effective Force that acts on an object is equal to the product of the mass of the object and the acceleration of the object).
   Also, in metric units, the vertical force due to gravity on an object at the Earth's surface is approximately 9.8 Newton (kilogram metre per second per second).
   And of course $\cos 30^\circ = .87$, $\cos 60^\circ = .5$, $\sin 60^\circ = .87$, and $\sin 30^\circ = .5$

7. You are standing at the top of a tall cliff, 100 metres above sea level. Looking straight out to sea, you lower your line of vision 30 degrees from the horizontal and see a ship. How far away is the ship?

8. Explain how we can mix the colors blue and yellow and get the result of green, and how we can mix the colors blue and yellow and get a resulting grey color, and how can we mix red and green and get yellow?

9. Homework Task: Use a mirror and a water-based fibre-tip pen (a washable whiteboard pen is ideal). Stand close to the mirror and look at your face. Consider how large it appears in the mirror—rather like looking at a person standing opposite you. Now take the pen, reach out, close one eye, and trace around the mirror image of your face. Now look at the oval shape you have traced. Does it seems as large as your face had at first appeared?

10. Consider the classic statement $3 + 4 = 7$. Match each of the following alternative answers with one of the following conditions.

    A  5
    B  10
    C  3.04
    D  2
    E  1

    (i) Adding so many dollars and some other many cents.
    (ii) Adding in modulo 5.
    (iii) Addition in base 7.
    (iv) Adding multiples of Aleph-nought, the smallest transfinite number.
    (v) Vector addition of perpendicular vectors.
Devil's Advocacy as Critical Research Methodology: Spatial Thinking as a Case Study


ABSTRACT
Playing a role of 'devil's advocate', although familiar generally within our culture, tends to be taken for granted, undervalued, neglected, or even held in ill-repute. Who wants to be on the devil's side when we could be on the side of the angels? But a devil's advocate wields essential critical and analytical tools which ought to be better understood and more deliberately used. What do you mean? How do you know? What does this imply? How would this alter current practice? What is the current practice that seems to be required to change? Why change? How could you test this idea? What difference does it make? Related issues such as the unthinking cultural acceptance of 'change is good' and 'change is progress', and 'critical fatigue', threaten to undermine reasonable principles of conservation. In my own work I find myself constantly playing a devil's advocate role, probing, challenging, and testing materials I read, the work of students I am supervising, and my own thinking and practice. I propose to discuss spatial thinking, and the related theories of Piaget, Van Hiele, and Krutetskii, in particular, as a brief indicative case study of devil's advocacy in practice.

Introduction: What is Devil's Advocacy?

'It's funny how many of the best ideas are just an old idea back-to-front' (Adams 1987, p 55.)

What is devil's advocacy? Like many important critical ideas, it is hard to pin down. But it is a way towards knowing. The hard-nosed economic rationalist, to take one approach to knowing something, says, in the lilting expression from the popular Hollywood film Jerry Maguire, 'Show me the money!', or 'What is the bottom line?'; which really means, 'How big a profit do I make?' or 'What will I have to pay for this?'. The empiricist says, 'Show me the evidence', or 'Why should I believe this?'. The devil's advocate is a kind of inverted empiricist. Instead of looking for reasons to believe, the devil's advocate tests proposed knowledge by looking for reasons to disbelieve whatever is being proposed. 'Why should I believe that?' or 'But how can I believe that when … ?'.

Traditionally a devil's advocate was the person appointed by the Pope or a college of cardinals, charged with the task of examining the life and works of anyone who was being considered for possible canonisation, a potential 'saint'. The devil's advocate's task was to test as rigorously as possible the saint-candidate's candidacy, searching for hidden sins, flaws in the character, doubt about the veracity of miracles brought about by praying for the saint-candidate's help, and so on. While purportedly putting the devil's case against the candidate being accepted into sainthood, the devil's advocate was actually a highly regarded member of the church hierarchy, and not, of
course, in any sense of the term, on the devil's side. But using the term more broadly, there is more to being a devil's advocate.

Working as a devil's advocate includes examining the terms and arguments used, considering alternative interpretations and potential uncertainties, proposing counter-arguments and looking for counter-examples and contradicting evidence, asking how the idea being proposed works in practice and what difference it makes, and investigating what would be the consequences if the proposed idea were actually not true. For me, a confirmed devil's advocate, it is my own knee-jerk reaction against unconsidered knee-jerk reactions to the latest breath-taking new idea that happens to come along, to the unthinking acceptance of band-wagon orthodoxies. Being a devil's advocate is also good fun because it gives plenty of scope to play, intellectually and critically, with ideas, sometimes pricking, plausible propositions. A devil's advocate is as rigorous in searching for counter-examples and counter-arguments as the opposition's (what might be called an angel's advocate) seeking of confirming evidence and supporting arguments, and in testing these is no less rigorous than his or her opponent's testing of the contrary case.

I should stress that being a devil's advocate does not mean believing in nothing (known in philosophical circles as nihilism, which might be linked with the Buddhist doctrine that the material world is an illusion). Nor is it simply nay-saying deny-everything cynicism. The line between constructive scepticism (looking for reasons that something might be accepted as 'true' as well as alternative reasons why it might not be 'true') and cynicism is blurry. But I like to think that I am a sceptic, a questioner, a person who does believe many things, but only when there is convincing evidence for doing so, and this evidence has been rigorously tested, counter-examples searched for and analysed, and so on. Aren't we all?

Perhaps this marks me, as I said in my symposium paper last year (1997), as an unreconstructed Popperian, following Karl Popper's view of scientific method, not as one of sifting evidence to confirm theories, but attempting to refute or disconfirm a theory. Recently one of the students I have been working with startled me with a passing mention of 'empiricists and post-empiricists, positivists and post-positivists'. Oh, no! I thought, not another post-blahblah to worry about. And, 'positivists'? Weren't they big back in the so called Vienna School, between the World Wars, Bertrand Russell and logical positivists, loosely linked with wild-eyed behaviourists such as B.F. Skinner—all foundering in the formal mathematical paradoxes of Kurt Gödel, and Wittgenstein's arguments about the unresolvable game-like ambiguity of informal language. It turned out that my student was reading the Handbook of Qualitative Research (Denzin and Lincoln, 1994 pp 5, 13, 109-110,) whose encyclopedic all-inclusiveness and rampant labelling results in two words for what I think of as empiricism, or scientific method. Certainly Popper made a major contribution to the philosophy of science. But despite his changed emphases and ways of describing scientific method, practising scientists went on in much the same way. There were not, despite the grandiose labels of the Handbook, two paradigms (another ugly word, which evoked all the ambiguity of Thomas Kuhn's famous discussion, and its rather confused aftermath), but one.

I mention this in some detail because it illustrates one of the features of devil's advocacy: namely, always wanting to know what a term means. (I am well aware that
as far as Humpty Dumpty is concerned words are simply there to do whatever we want them to do—'the question is … which is to be master', you or the words: Carroll 1871 chap VI.)

There is more to this than often meets the eye. A devil's advocate also wants to know what a term doesn't mean, and what a term is different from, and what a term is good for. A term which looks as though it specifies something, but actually includes many other things as well, maybe too many other things, is useless. Well chosen, clearly defined terms capture precise, or at least reasonably clear meanings, and just as clearly exclude others. Why? Trying to come to grips with knowledge, at least for me, is purposive. I don't just collect knowledge, I want to be able to do something with it, such as answer questions, and understand things which have puzzled me, and sometimes to actually do something, such as use computer graphics to make isometric drawings, or learn to program using Logo, or design and build a coffee table, or write a book, or a paper about research methodology—such as this.

A Devil's Advocate is a Jargon-Buster

Postman and Weingartner (1969 p 16), typically, attempting to express their radical sense of the real point of schools (knowledge-communication factories), quote Hemingway's interview remark that necessary equipment for a great writer includes 'a built-in, shockproof crap detector'. This is one of the functions of devil's advocacy — detecting crap. Showing that some proposed idea simply cannot be believed, because of reasons X, Y and Z. Sadly, it's easy to be taken in by crap. Sometimes we are willingly gullible, and refuse to test the evidence for or against. Humans are not always consistent or logical—they can't be. It is part of human nature to live, as well as possible with paradox and contradiction. It is, stating a truism, certain that I will die, and that whatever I do in my life will make no discernible difference to the universe in one hundred, or one thousand years—but I go on doing it just the same, as though I could make a difference. And maybe I can, for a very short while, make a difference. But I know any difference, any ripple I cause, will quickly enough disappear. This is the paradoxical wisdom of Albert Camus's existentialist novel The Plague (1947)—brutal, but enough to build a life on.

'Why sometimes [said the White Queen] I've believed as many as six impossible things before breakfast'. (Carroll 1871 chap V.) When Lewis Carroll invented the White Queen she was a figure of absurd humour. In our age of quantum theory, political correctness, and post-modernist post-deconstructuralism the White Queen is seen as heroic—if only we could attain her intellectual strength. Douglas Adams realised this when he invented the Electronic Monk, a labour-saving device, like a washing machine, which saves you from having to believe 'all the things the world expected you to believe' (1987, p 3).

Why do we need crap-detectors, or to test definitions, or search for counter-examples (as Imré Lakatos argued, in his Popperian discussion of the 'proofs and refutation' method of making mathematics, which last year I argued had its natural counterpart in constructivist theories of learning mathematics, or anything else: Lakatos 1974)? Partly we need it as an act of critical self-defence, because we live in an age which has sanctified 'change'. New is good, newer is better, change is good, change for change's sake, and hooray for progress!
Critical Fatigue and the Chimerical Drive for Novelty—Post—... What?

One driving force behind this intellectual pro-change culture is a kind of 'critical fatigue' or 'intellectual habituation'. Ernst Gombrich describes this in his major study of the psychology of decorative art, *The Sense of Order* (1979). He notes 'the undeniable psychological fact that the familiar tends to register less than the unfamiliar, and that the public therefore demands ever stronger stimuli' (p 212). He further comments that this links with 'the tradition of the new', the ceaseless search for 'originality', '… ranging from a mild interest in innovation to the impatient rejection of last year's model' (p 213). Against this, a practical minded devil's advocate retorts, if it ain't broke, don't fix it! Hold fast that which is good. Are there any healthy babies being thrown out with this ageing bathwater? The same idea arises in John Brophy's neglected Second World War novel *Immortal Sergeant* (1942 chapter 6): 'the programme for a concert had to be compiled carefully. The public loved its familiar classics … but the critics had heard them too often. You had to lure the critics with something new, which was hard to get, or by a bit of showmanship'.

Incidentally, why am I pillaging novels and books on decorative art to make a point about educational research methodology? It is because I am a rag-bag eclectic (not, I hope, a rat-bag eclectic). As the trendy French would put it, je suis un bricoleur, using Claude Levi-Strauss's bizarre and alienating terminology (e.g. Levi-Strauss 1966 p 17, or Papert 1980 p 173, or Denzin and Lincoln 1994 p 2). Sadly, it is typical of much that a devil's advocate would find wrong with trendy research jargon that we do not insist on clear English for a simple idea. But of course this use of obscure foreign terminology adds a sophisticated highly intellectual sense of … je ne sais quois (which, though it may sound very smart and impressive, means, literally, 'I don't know what', which does rather sum up the unhelpful point of obtuse abstruse terms). Unashamedly I am a dog's-body theorist: I practise bricollage; that is I am a Jack-of-All-Trades, a do-it-yourself-er, who finds that similar ideas arise in diverse settings. Naturally they 'arise', because my mind sees them there. It is typical of human thinking that we see life through our own thinking and experience, through personal lenses, whatever we are looking at. Inevitably, then, much that I read or hear becomes grist for my own mill. Isn't this true for us all?

Critical fatigue or overload, of course, explains a lot of the bizarre stuff that occurs in 'modern' and 'post-modern' art, to say nothing of the well-intentioned hyper-imaginations that have arisen in educational thinking, and practice. Again, the possibility of creating a label may actually serve as a conceptual trap, creating a semblance of something that may mislead us into thinking we are seeing something which is actually not there, clothes on the naked Emperor. What, for example, is 'post-modernism'? If we take literature as the arena for asking such a question, what might be exemplars of 'post-modern' novels? John Fowle's *The French Lieutenant's Woman*? Gary Crew's *Strange Objects*? Joyce's *Ulysses*? Sterne's *Tristram Shandy*? Petronius's *Satyricon*? Almost any characteristic of so called 'post-modernism' can be found in books which are so old that they make nonsense of the 'post-' or the '-' modern.

What about education? Do we actually live in a 'post-modernist' age, and if so, where was the 'modernism'? Profiles? New math? Programmed learning? Behavioural

So much, perhaps, for deceptively attractive, attractively deceptive terms. Similar difficulties of terminological inexactitude arise with terms such as 'information technologies, learning technologies, technology, convergent technologies, numeracy, and the Internet. Would we, for example, speak of a computer as an example of technology? A typewriter? A pen? Is the alphabet a form of technology? Where do we draw the line so that on one side the examples represent the concept of technology, and on the other side the examples are not-technology?

Active Learning — Sounds Good, But Could That be Right?

As another example, I frequently encounter the idea that students were in some earlier era not-active learners, with the suggestion that now the Internet, or computers (or Cuisenaire, or New Maths) will miraculously make students active learners. But this is largely spurious. When we are carry out large quantities of education, especially of people younger than 20 years of age, pre-employment people, there is a great deal of compulsory about this learning and, because students have little choice, compulsory education often has an appearance of students not being active. Being interested and being active are not necessarily the same. But students, whether studying voluntarily, or compulsorily, within a formal educational setting, usually do what they are told by their teachers. This 'doing' is 'active'. Equally, students learn by actively connecting with information and experience (mentally active, even if not always physically active and wandering around classrooms or jumping around in gymnasiums, or performing in some way, such as practising a musical instrument, or using a spoken or written language). Even in the strict methods of teacher-dictation, student-memorisation, and rote performance, students were 'active' in their attempts to memorise, and, even with rote-intended instruction, to make some kind of personal sense of what is expected to be learned.

It may also be noted in passing, in our age of student-centred approaches to learning, and teacher-as-facilitator, that not only are students actually active, so must teachers be. The whole point of being a teacher is to make a difference, to change the students, to bring about learning. Putting this provocatively (and being a devil's advocate is often a matter of acting as an agent provocateur, a possum-stirrer or pot-stirrer, a provoker, a thorn-in-the-side, a nagging conscience, a voice in the wilderness, a prophet not honoured in his or her own country), a teacher is paid to interfere with students' minds, and any teacher who is not doing this is simply child-minding! This does not mean that a teacher must run classes with a rod of iron, or totally dominate. But it does at least mean that the teacher is accountable for the learning of students, is in control of the class, and directs the activities that occur in the class. Certainly students can be consulted, and may even make significant contributions to any decisions about what is to be studied and learned, to what will be the focal activities of the class. But the teacher remains dominant, in the way that the compere of a TV show dominates the discussion of the guests, and ensures that things run smoothly, and that the discussion is worthwhile and substantial and pleasant.

Of course a teacher must listen to what students say, and be able and willing to respond to this. The teacher must also leave space, and time, in which students can
think and work without continual prodding and input from the teacher. But most of what the students will be engaged in will be material, questions and challenges provided by the teacher, essential stimuli and motivation. Without this direct intervention and contribution ('interference', indeed) by the teacher, left to their own devices, most students would be quite pleased, for example, never to do any mathematics at all, and instead spend all their time chatting about TV, playtime, looking forward to lunch, gossiping about classmates, playing games, and so on. While it is true that students do learn informally and spontaneously in non-school settings, and it is the goal of schools and teachers for their students to become increasingly independent of direct teacher-input, most of the learning which occurs in schools which are established for the purpose of compulsory education occurs precisely because of the action and initiative of teachers. The older the students, the less reliant on teachers they should be, but now I am speaking ideally—even devil's advocates can be idealists.

Oh Brave New Computer-Crazy World — 'New'? Different?

One of my students picked up a point from other researchers: 'The type of student in our classroom today, is as Green and Bigum mention (1993 p 119), quite different to previous eras'. But the devil's advocate in me disagrees. Certainly the student has new tools. But the student's approach to learning is the same as it always was—teachers often having to drag them to the actual learning, kicking and screaming—'Why do I need to know this? When will I ever use it?' Unfortunately, although Green and Bigum are exciting to read, and often provocative, they frequently exaggerate for rhetorical purposes or just simply get things wrong. Think about the students you teach. Making some allowance for comparatively recent generational changes in popular culture (rock video and computer games, for example), are these students really different from the way you and your friends were when you were in school? Or when your parents were in school?

To push this argument a little further, consider the glowingly recommended attributes of computers in schools recently offered to me by another of my students: The computer is a:

• think pad;
• key to access data from Encarta to Reuters;
• tool to store, organise and manipulate information;
• doorway to the most powerful multimedia formats;
• construction site for learning;
• gallery to exhibit knowledge and understanding;
• multi-dimensional tool in a multimedia age; and
• communication tool to express feelings, share ideas and to develop powerful relationships.

But as a devil's advocate, let me also point out that:

• an exercise book is a think pad;
• a library gives access to data;
• algebra, calculators, encyclopedias, measuring instruments, and so on, are tools for working with information;
• paper-based education, which I am talking about here, is a doorway to many publication-formats;
• discussing ideas with people, and working intellectually with recorded forms of knowledge is a way of constructing learning, and anywhere that you do this is a construction site, even a blackboard can be a construction site;
• a gallery is a gallery, and so is a concert hall, a sports arena, a dance floor, a book, or billboard, or broadcast, or lecture, or other form of public or shared communication;
• pens, paints, printers, stamps, scissors, paste, audio-recorders, video-recorders, editing machines, and so on are each of them dimension-tools in a multi-dimensional information age; and
• talking, singing, dancing, gymnating, playing, miming, writing, acting and interacting are communication tools to express feelings, share ideas, and develop powerful relationships — more powerful, we would hope, than anything mere machines can develop, because people interacting with people face-to-face is more immediate and mutually supportive than anything that can be seen and reacted to on a computer screen. Of course, when robots pass the Turing test of detectable intelligence, my remark about face-to-face will come unstuck.

What I am trying to get at here is a counter to the underlying naive enthusiasm of the student, who seems to be offering these views of computers as though this is all new, an amazing breakthrough in learning tools.

We have, in fact, had other versions of these tools, in the past, which were often as effective as anything a computer can do.

'Well, what we called a computer in 1977 was really a kind of electric abacus, but …'
'Oh, now don't underestimate the abacus,' said Reg [the Regius Professor of Chronology at St Cedd's College, Cambridge], 'In skilled hands it's a very sophisticated calculating device. Furthermore it requires no power, can be made with any materials you have to hand, and never goes bing in the middle of an important piece of work'.
'So an electric one would be particularly pointless', said Richard [a former college student, and computer programmer] … 'There really wasn't a lot this machine could do that you couldn't do yourself in half the time with a lot less trouble… .' (Adams 1987 p 19.)

We get a similar unthinking knee-jerk rejection of the so called 'empty-vessel' theory of knowledge. But think of your own experience as a student in school. Did you ever feel you were an 'empty vessel'? Do you think your teachers ever treated you as an 'empty vessel'? And, if so, how could it have been different? Think now of your own work as a teacher. Isn't it true that, when you set out to 'teach' something, you start by assuming that, whatever it is you are about to teach, your students do not already know it, at least not in the way you want them to know it—or else there would be no point in teaching it! Hence, as far as this particular topic is concerned, these students are 'empty' of that topic, or at least 'naive' about the topic. They may know the topic exists, but not really know anything about it, or know wrong things about it. That is, the 'empty vessel' metaphor, like many metaphors, is partly right, and partly wrong, and should not be unreasonably pilloried, nor should something alleged to be a non-empty-vessel theory be held up as a panacea.
The same student, sketching the impact of 'learning technologies' on schools, argued that:

  in a student-centred learning environment, especially one supported by the use of technology, the role of the teacher, far from being diminished is expanding and becoming more demanding and challenging. Far from abdicating their responsibilities or being replaced by machines, teachers are playing a far more active role in student learning, one to which the term 'facilitator' does not do justice. They need to:

  • support students in taking responsibility for their own learning by giving students ownership of the learning process;
  • structure activities to incorporate computer-mediated technology when and where appropriate;
  • ensure the development of 'information literacy';
  • encourage students to seek advice and information from 'experts' beyond the classroom, whether through the Internet or through mentoring arrangements;
  • encourage collaborative, project-based work to help students to be good local and global citizens;
  • assist students in reflecting on their learning and in developing more effective learning strategies and in developing all aspects of their 'intelligences';
  • ensure the development of appropriate ethical standards of behaviour towards the sensitivities of others, intellectual property, data privacy and the integrity of systems and networks; and
  • be co-learners with their students in using the technology effectively.

But, wearing my devil's advocate hat, I'm not sure there is much here that hasn't always been true about the role of teachers. Changes in technology do not alter this, not that much.

Similarly, consider this idea proposed by a student:

  'If the teacher can design an activity which uses the computer and also has some relevance to the students' life-worlds, the students are more likely to construct meaningful mathematical knowledge'.

Certainly this idea would be good, but hard, to research. However simply using computers may not make the learning any more meaningful.

Consider, for example, whether or not Secondary mathematics students are currently learning, say, standard deviations, any more meaningfully now that they routinely use scientific calculators compared with the old days when all calculations were done using formulas and pencil-and-paper, or even using non-scientific calculators. It might be the case that the computers actually distract students from the real focus of the learning, or conceal the educational goals. We might think Secondary algebra students are learning, say, how to solve and manipulate quadratic equations, but they are actually only learning how to run a part of Mathshelper or some other mathematics processing software, and not really grasping the idea, say, of completing the square. In fact, using computers, would they ever actually see the 'square' that is being completed, and what does the 'completing' idea really mean unless it is actually seen?
Students Really Learn By Really Doing Projects — Really?

We need to be constantly on critical guard against claiming things to be true which we want to be true but which might not necessarily be the case. We need strong devil's advocates to protect us from being too hopeful. Nowadays, in the era of CATs (Common Assessment Tasks—namely, projects and examinations) and problem-solving projects, students are asked to complete a large investigative project, requiring students to apply and extend their existing 'tool-kit' of skills and concepts to new situations. Such a project, or the stages in exploring and solving a large problem, may involve considerable quantities of important mathematics, and the educational rationale for such projects is held to be that it reflects the real way that mathematicians use mathematics, and it provides a context in which mathematics curriculum is learned more effectively by the students.

Really? Sometimes all the students are aware of having achieved at the end of such an investigation are some answers to the overall project problems. The mathematics the students have used does not really sink in, certainly not in a general sense, because the students only ever see this mathematics as a means to an end, not something that might be used in many very different situations, or that might meaningfully connect with other important mathematical ideas. Imagine, for example, setting the students a task of finding the speed of a falling object at a given instant. While this might involve a lot of calculus-related mathematics and thinking, the students may learn virtually no calculus at all from the activity, even though the students do obtain a reasonably correct answer using mathematically rigorous arguments.

If students are to develop their understanding they need to be able to look up from their narrow focus on getting answers, and examine and generalise the task-specific method they are using. In effect they must say to themselves, 'I have found an answer to this particular question, but what other kinds of questions can I use this method to solve, and what is this method really doing?' Moreover, far from appreciating that this is the way real mathematicians use mathematics, students come away from the project with a sense of having done what the teacher asked them to do: haven't students always focused on their own private game of 'Please the teacher, and avoid trouble?'

Here is another example of glowing student-oriented rhetoric which ought to be challenged.

'When students construct their knowledge, teachers must let them link their learning of concepts in their own way. If we let children (or in fact anybody) follow their own noses, learning anything that they are curious about, they will go faster and cover more ground than we would ever think of trying to set out for them, or make them cover.'

Arguing as a devil's advocate, if students are left to make their own connections, or left too free in their connecting, they easily get things wrong.

Notice the way students use their own terms, such as 'timesing' instead of multiplying, or develop idiosyncratic informal methods for doing arithmetic (adding the tens first and the units later). Consider the scope for mis-learning when students interpret too freely or in ignorance. Remember the child who called her teddy bear 'Gladly' because her teddy was cross-eyed and she knew the old hymn tune 'Gladly My Cross-
eyed Bear'. Think of the scope for students to get things wrong, or rely on formulas, when they think of 'limit' in terms of plain English everyday meanings, or just plug values into \(^nP\) and \(^nC_r\) instead of arguing step-by-step from first principles.

When glowing rhetoric and newness is pursued relentlessly, with little attention paid to earlier practices, inevitably the history that is not remembered is repeated. Guided reading, for example, the latest fashion in classroom reading methodology, is simply a re-invention of a whole class all reading the same book aloud. In this case, the devil's advocate notes wryly, the more things change the more they stay (or eventually become) the same, again.

Moreover the **Hawthorne Effect** is not as widely known as it ought to be, the experimentally demonstrated result that, while participant-subjects believed they were involved in some new experimental treatment, their general performance was boosted, until they became used to the newness. Hence novelty has a genuine teaching value, but not because the new ideas are necessarily good, in themselves, but simply because they are regarded as new. Once the newness fades with time, the artificial boost in motivation and consequent achievement disappears, unless there really is some previously-masked benefit in the now-aged innovation (McMillan and Schumacher 179–180; Ary et al. 226). A devil's advocate knows all about the Hawthorne Effect, and cautions against being misled by it.

**The Great Piagetian Breakthrough — Are Children Really Like That?**

I may have always been a devil's advocate — haven't we all. But perhaps Piaget first triggered my conscious critical reactions. Fascinating though the experiments were, the interactions between child, experimental task, and clinical interviewer, I repeatedly found myself not believing what were claimed to be the results.

   Adult: Are there more flowers or more daisies?
   Child: More daisies.

   *(From a transcript of a Piagetian interview in a Nuffield film 'Children and Mathematics, quoted by John Holt 1970 p 63.)*

Holt, puzzled by the child's reply, quotes unpublished remarks of Tony Kallett, a British school adviser: 'the child's job is to figure out what the adult expects him to say, and the adult's job is to make this as easy as possible for the child' (p 64). Holt himself is blunter.

   'Alternative answers have been on the following lines:
   (1) Huh? You can't ask that;
   (2) More [flowers] naturally;
   (3) Huh? What do you mean?' (p 66).

That is, too often, Piaget's interview script or use of language or experimental task is so unusual that children are tricked into giving answers which do not reflect what they really think. The more I read about Piaget, including critics such as Charles Brainerd, Graeme Dettrick, Peter Bryant, and Martin Hughes, the more I was impressed by Piaget's hard work and innovative thinking, and the less I was impressed by his research conclusions. In fact Piaget, with his famous 'concrete operations' and 'Stage' theory, was not himself all that original. In the fantasy novel *The Crock of Gold*, the Irish novelist James Stephens noted that 'With children, thought cannot be separated from action for very long. They think as much with their
hands as their heads. They have to do the thing they speak of in order to visualise the idea' (1912, Book VI, chapter XVII, pp 149-150).

Seymour Papert, the inventor of Logo, gives a fascinating account of his childhood experience with cogs and gears — 'I became adept at turning wheels in my head and at making chains of cause and effect'. Later Papert used gears as mental models when he first encountered the ideas of multiplication tables, and equations with two variables in algebra (1980 p vi).

This is not an argument for introducing gears into kindergarten. However it was precisely in order to provide a similarly powerful semi-concrete context that could help students experience and think about mathematics that led Papert to develop Logo.

Peter Sullivan describes a related example, where a concrete object, surprisingly enough, enabled a student to think very quickly. One day he asked his son, then in Grade 1, 'what's fifteen plus sixteen?', and was surprised by the speed with which his son answered 'thirty-one'. The answer came too quickly for a digit-by-digit mental counterpart to a pencil-and-paper algorithm. Had he used the well known strategies of near-doubles or double-and-adjust? Had he for some reason memorised a number fact and recalled the result? His son explained that he knew 'fifteen minutes is a quarter of an hour, and thirty minutes is half an hour, so thirty-one' (Sullivan 1994 p 12).

From this we can conclude that it is extremely difficult to effectively prescribe concrete materials as essential components of the mathematics curriculum. Some children benefit from some materials some of the time. But, like Abraham Lincoln fooling the people, not all children benefit all the time from any particular material. My oldest son, who started Primary school already able to calculate mentally, using informally developed counting strategies and 'just knowing', which is, of course, the central goal of the mathematics curriculum, soon stopped being able to do this, precisely because a misguided Prep teacher believed that all children needed to rely exclusively on concrete materials when they started doing number work in schools. Grrr!

In this case, who could have predicted that a Grade 1 student would have mentally internalised such information about analog clocks, or be able to connect the clock image with a number fact? Yet this is, obviously, the way students think, albeit, idiosyncratically. This is not an argument for making analog clocks a compulsory concrete aid for all junior Primary arithmetic learning. But teachers need to encourage their students to use such personally significant concrete models as a natural informal aid to related thinking activities.

These examples show the power of first working with objects, and then thinking about them, automating and internalising, a key process in constructivist theory, as I noted last year (Gray and Tall 1994). In fact it could be argued that one of the important factors in Piaget's interview work is that so much of it is oral, naturally, with children who have not yet learned to read or write. Yet the internalising and automating of written language skills brings with it a lift in vocabulary and a change in thinking which may have a significant effect on thinking generally. How many of
us find out what we think by the exploratory process of trying to write down our ideas? 'The little girl had the makings of a poet in her who, being told to be sure of her meaning before she spoke, said: "How can I know what I think till I see what I say?"' (The Art of Thought, Graham Wallas (1858-1932) — I have been unable to find a full reference for this quote found in the Penguin Book of Quotations).

**Pictures Also Need a Devil's Advocate**

Words, of course, are not the only arena for devil's advocacy. Consider the following simple example which was offered by a visiting North American academic as a model for explaining the dynamic connection and interaction between three kinds of information or experience, such as: Language, Actions, and Attitudes; or Mathematics, Science, and Technology. Criticise the diagram.

I leave as an exercise the following diagram, which is meant to serve as the 'conceptual model' for teacher education in a nearby country. I am assured by one of my students, a lecturer from a teachers' college in this country, that the diagram is very well understood by teachers and educational professionals. I am not so sure that there is ANYTHING that is understandable, but it is most unlikely that my critique would have any effect: as the Americans say, 'You can't beat City Hall'.

![Diagram of Belief in God](Image)
Consider, for example, the Venn diagram (is that what it is?) in the centre of the diagram, and the perpendicular bi-polar axes (Spiritual–Physical, and Intellect–Emotion) which are (apparently) overlaid on the over-lapped circles, and ask how these seven words are meant to be connected, or how the inner parts of the diagram are meant to connect with the outer vertices of the triangle.

**Theories of Spatial Thinking: A Case Study**

Are there 'stages' of development in learning about Geometry and thinking spatially? The famous Swiss experimental psychologist and education theorist **Jean Piaget** devised many ingenious experiments and used these to develop extensive theories about the way people learn about 'space' in the world around them. His major study with Bärbel Inhelder *The Child's Conception of Space* (1948) argued that infants and children progress in geometric knowledge from topological concepts, through projective geometry and eventually reach Euclidean concepts only with the advent of formal school instruction — a surprising reversal of the actual historical development of theories of geometry in mathematics.

But this says more about Piaget's personal philosophical tendency to look for surprising evidence of abstract modern mathematics in children's thinking than it does about either the history of geometry or what children really can or cannot do. Despite this, Piaget has been very influential. (Generally I subsume Inhelder into the use of the name 'Piaget' in this discussion, not to belittle her work, but in recognition of Piaget's pioneering significance.)

Without going into too much detail consider briefly one of Piaget's more intriguing and appealing spatial experiments: the classic 'Three Mountains' task, which Piaget describes as 'co-ordination of perspectives' (1948, pp. 210–246). The apparatus consists of a physical table-top model of three mountains, shown in the sketch in Figure 1.

![Three Mountains Task](image-url)

**Figure 1: Jean Piaget's 'Three-Mountains' Task**

This should be easy for picture-literate adults to understand visually. Obviously for the young Swiss children Piaget interviewed and studied, Alpish mountains were certainly part of their everyday experience. (But consider how Dorothy on the prairie plains of Kansas might respond to Piaget's questions!) Each mountain has identifiable features such as height and color, a snow cap on the highest, a hill-top cross on the second highest, a red house on the top of the lowest of the mountains, not shown in this sketch. The child must identify a particular pictorial representation of the three mountains as seen from a specified position. To do this the child chooses from a collection of realistic pictures of this model as drawn from several different points of view. (Experimenters nowadays would use close-up scale-model photographs instead of Piaget's drawings.) The child is helped to do this by the experimenter using a toy
doll who is supposed to be moving like a real person around the model of the mountains as though the mountains and the doll were real.

What will the doll see when it stands here — at A, B, C, or D, and so on? Piaget had several different ways of asking these kinds of questions.

He interviewed 100 children, ranging in age from 4 years to 12 years old. As a result he described several major Stages in development, each with important sub-Stages—all part of a much larger general theory of cognitive development through childhood—the classic Pre-Operational, Concrete Operations, Formal Operations theory of Piaget.

In short, the youngest, or least developed children who could understand or seem to respond sensibly to Piaget's questions did not identify the point-of-view of another observer: 'the child distinguishes hardly or not at all between his own viewpoint and that of other observers (represented by the doll in different positions)' (Piaget & Inhelder 1948, p. 212). For such a child, when attempting to imagine another person's point of view, the child believes that anyone else will see only what the child sees. The child cannot see beyond his or her own point of view. The child is locked into 'egocentrism'.

Very interesting. Such children would be baffled by instructions from pre-school and school teachers to perform spatial tasks needing an imaginative response to another's viewpoint. Cooperative play with building materials would be extremely difficult.

**Martin Hughes Versus Piaget**

It takes a devil's advocate, a brave researcher with an equally intriguing experimental set-up to challenge such impressive research. Martin Hughes, the author of *Children and Number* (1986), developed a simple counterpart to Piaget and Inhelder's 'Three Mountains' (in Margaret Donaldson's classic *Children's Minds*: 1978, pp. 19–31): a cut-away house, with a policeman-doll and a boy-doll shown in the bird's-eye view of Figure 2.

![Figure 2: Martin Hughes' 'Policeman and Boy' Task.](image)
The boy doll can be placed at positions A, B, C or D. The child is helped to understand the equipment. Questions are asked such as, 'If the policeman stands here [as shown] and the boy is here [e.g. A], can the policeman see the boy?'; 'If the policeman is here [actually placed at B, for example], place the boy so the policeman can't see him'. Very few errors occurred, and children were helped to overcome any errors. This led to the real test: two policemen were placed in different locations, and the child had to try to hide the boy-doll.

Where Piaget found that children up to the ages of 8 and 9 were unable to answer 'Three Mountains' questions correctly, unable to 'de-centre' (nasty jargon) or overcome 'the egocentric illusion' (Piaget's words, translated, quoted by Donaldson, p. 20), Hughes found that children aged between three-and-a-half and five years could answer his 'Policemen and Boy' questions with an overall accuracy of 90 per cent. And four-year-olds could handle even harder questions with the same success rate. Who is right?

Piaget's work has been replicated by others. Hughes' work stands up to experimental scrutiny. What is at stake is the interpretation offered by both researchers, and critical comparison of the two experiments. According to Donaldson the key difference is that some of Piaget's younger children actually did not understand the task, although this seems not to have been obvious to Piaget. Hughes was able to use a simplified version of the 'Three Mountains' task with pre-school children and, given careful help to make sure they understood what they had to do, most of them succeeded.

But more importantly, Donaldson points out that even three-year-old children know what is involved in 'hiding' from some one. Though of course few children are used to really hiding from policemen, 'hiding' is a widely played young child's activity. That is, the Policeman task 'makes human sense' (emphasis in Donaldson's original, p. 24) where Piaget's task is clearly harder and also less humanly sensible because the motives and intentions of the imagined players in the task is not obvious.

This discussion of two key research experiments indicates the caution we need to exercise when faced with apparently compelling experimental evidence that children can or can't do certain things—or that they pass through certain stages at particular ages. There is a difference between being influential and a pioneer, as Piaget unquestionably has been, and being reliably right and helpful in the classroom. A devil's advocate tests these differences.

**Piagetian Disciples — van Hiele's Developmental Theory of Geometric Learning**

Consider another increasingly popular theorist-researcher of spatial thinking. Just as Hughes came to his research in critical response to Piaget's influence, in the 1950s the Dutch Pierre van Hiele and his wife Dina van Hiele-Geldof attempted to build on and 'correct' Piaget. They constructed a developmental theory about geometry, building on the responses of school children to instruction in traditional (Euclidean) geometry. This research began with two parallel doctoral studies. Following the early death of his wife, van Hiele continued their joint work, and his research articles and major study *Structure and Insight* (1986) has had considerable continuing influence. The following discussion draws on the Australian-based research of John Pegg.
According to van Hiele, students move through five identifiable Levels of thought or geometric understanding, as follows (adapted from Pegg 1990, pp. 427–428):

**Level 1**: Students identify figures by their shape as a whole. An object (say a trapezium) is what it is because it looks like it, a square and a rectangle are seen to be different. A typical comment from a student at this level is that 'a rectangle is a longer square'.

**Level 2**: Students identify figures by their properties. However, the properties are independent of one another. A typical response might be 'a square has four equal sides and four equal angles'. Squares and rectangles [which share some of the stated properties] are still seen to be different.

**Level 3**: Students still identify figures by their properties, however relationships between properties are observed. A typical response might be 'an isosceles triangle has two equal sides', but if probed about the angles the student will say 'if the sides are equal then the angles opposite them must also be equal'. A square is now seen to belong to the class of shapes called rectangles. Concepts such as parallelism and congruence emerge as principle aspects to be explored and used even though they had been known and talked about at lower levels.

**Level 4**: Students can reason in a formal (deductive) way. They can solve theories [or 'theorems'] without relying on rote learnt steps that need to be followed.

**Level 5**: Students can work within systems based on different axioms and study other [non-Euclidean] geometries which are not based directly on [Euclidean] experience. An example would be projective geometry.

We notice in the examples offered by John Pegg the typical sequence by which students at first distinguish in everyday terms between 'square' and 'rectangle' (and the term 'oblong', which is an everyday synonym for the mathematical term 'rectangle'), and only later accept the mathematician's view that a 'square' is a special case of a 'rectangle', and also that a 'square' is a right-angled example of a 'rhombus'. In fact 'rectangle' and 'rhombus' are also included in the larger category of 'parallelogram' and this is in turn included in the still larger category of 'quadrilateral', itself a category within the general family of 'polygons'.

The successive development of finer and finer distinctions between definitions or categories is often conceptually problematic for students. The example of 'square' and 'rectangle', initially discrete concepts, later being seen with 'squares' as a subset of the set of 'rectangles', is a classic example. Exactly the same difficulty arises in the successive refinement of zoological concepts. Typically, many students at first find it shocking or at least puzzling to include 'birds' as a subset of the larger category of 'animals', and commonly rebel at the teacher's suggestion that 'humans' are also 'animals'.

Van Hiele and Pegg are right in their analysis and description of a theoretical intellectual sequence of levels of understanding—from everyday concepts to formal definitions and abstract deductive skills. But whether this has any relation to psychological developments within an individual or learning stages is another matter—grist for a devil's advocate.
For example, notice that Pegg's account of van Hiele's theory Level 5 assumes that direct experience of geometry is 'Euclidean'. But whatever the limitations of Piaget's research, it seems clear that infants' and very young children's perceptual world and thinking is based on the non-Euclidean concepts of 'near, far, in, out, touching, not-touching' and so on. That is, so called 'direct experience' may not be inherently Euclidean at all. After all, Euclid proposed his geometry after millennia of human activity with informal geometric experiences, and non-Western cultures did not develop Euclid's formalisations.

Straight lines, angles and so on are human conceptual constructions which provide an abstract basis for certain kinds of human activities. We only need to step into a world of plaited wattles and round-walled round-roofed mud-thatched huts, or the well-known hemispherical Inuit igloos, to realise that 'straight' and 'angle' are also culture-relative, and not necessarily part of direct experience unless you happen to live in a world built of bricks and planks and right angles, dominated by tools and machines and school-based approaches to language and concepts.

The van Hiele Levels are certainly interesting. Pegg and others have used the Levels as structural guides for approaches to developing geometric curricula. For example Pegg suggests that teachers encourage students:

- to concentrate initially on the properties of a rhombus. Not until students are familiar and comfortable with these properties is it suggested that work involving [compass-and-ruler] constructions (such as bisecting a line and drawing perpendicularly) should be commenced. Such an approach allows teachers the chance to let students, who are at Level 2, work at their level of understanding in carrying out and explaining constructions (a topic teachers often cite as difficult to 'teach'). The end result of such an approach is that students can talk about the reasons why the constructions 'work' in terms of the properties of a rhombus. They do not need to rely on remembering a number of 'tricks' that they do not understand and need to memorise (Pegg 1990 p 428).

This sounds convincing. But so did Piaget's 'Three Mountains' research. Let us now consider what possible flaws a devil's advocate might be in such a view?

To begin with, van Hiele and those who use his ideas, seem to be confusing the idea of 'development' with the experience of schooling. Piaget's theory, with its Stages of Pre-Operational, Concrete Operations and Formal Operations, argued that children cannot be 'taught' how to move from one Stage to another. Rather, if a teacher has any role in helping students move onwards through their cognitive developmental stages, it is only to provide as much rich and suitably structured experience as possible, from which students will be able to make their own discoveries and 'grow' through this experience to a new way of thinking. Pegg, discussing the reported difficulties with compass-and-ruler constructions, is similarly hesitant about the possibilities of 'teaching' being effective.

But Piaget's ideas, about providing rich experience and challenging materials and activities, distinguish between traditional approaches to school curricula (lesson A, followed by lesson B, and so on, developing concepts and skills in order x, y, z, and
so forth) and a kind of uncontrollable mental growth that corresponds with physiological growth (such as the onset of puberty, given a sufficiently nutritious diet). You can't teach people to become taller. You can't teach children to physically mature into adults. You can't teach people to move from Concrete to Formal Operations. But with a good enough 'diet' or experience, they will get there themselves — according to Piaget and Piagetians.

Whatever we may think of such claims, this is obviously very different from any comparable claim by van Hiele or his followers that you can't teach people to move from, say level A to level B. Different, precisely because van Hiele's identified Levels are so clearly tied to different stages in a traditional geometry curriculum. It seems impossible to imagine any way that a student could move from, say, Level 3 (structured geometric vocabulary) to Level 4 (standard Euclidean proofs), or from Level 4 to Level 5 (non-Euclidean geometries) except by the direct intervention and instruction of a teacher wielding a well structured geometry curriculum. Whereas it is possible to imagine a student moving from Piaget's Pre-Operational to Concrete Operational Stages simply through rich experience and natural 'growth'. Isn't that how most of us did this, and our children after us? Surely we did not rely on a teacher and formal instruction, or informal parental hints.

As for moving from Concrete to Formal Operations, especially in mathematics where the move is one from number work to algebraic work, and beyond, it is extremely difficult to imagine how this can be done without teachers. But that is yet another criticism of Piaget's theories which need not detain us too long here. The more you take a devil's advocate look at hard details of school curricula, the more Piaget seems to have less and less immediate relevance or constructive implications for the business of teaching and working with children and their school-based mathematical thinking especially in the transitional stages from arithmetic to algebra. (Further details can be found in the specialist research discussion by Clements and Gough 1978.)

Separate from these remarks, notice also the way Pegg, for example, emphasises that students should focus on restricted geometric topics, such as the rhombus, until these are 'mastered' or sufficiently understood to be able to become the basis of extension to further and other topics. But Pegg himself identifies a key limitation:

... if this idea was pursued in detail then the process would need to be repeated many times (i.e. with many figures) before a satisfactory basis, across a large section of Geometry, was established ... apart from the tedious repetitive nature of the activities, it is not clear that the sum of the repeated procedures would ever give a satisfactory holistic answer for the student (Pegg 1990 p 430).

Pegg's discussion goes on to consider van Hiele's suggestions for overcoming this limitation. However the overall implication seems to amount to little more than the obvious point that teachers should proceed to teach geometry as well as possible, bearing in mind that students may not always understand at first, and may take time to come to grips with the real implications of the curriculum.

In the extreme case, we might accept van Hiele's theory, and claimed that this should form the basis for teaching geometry in school, because it has been shown experimentally to be the way that geometry is actually learned. But against this we
simply need to ask ourselves whether this was, in fact, the way we learned geometry? Obviously, because we would not accept any suggestion that we have not ourselves learned anything about geometry, there are other ways of learning geometry. Are they as effective as van Hiele? That could be researched. But van Hiele's analysis itself is not evidence for this.

Krutetskii and Two Forms of Mathematical Thinking: Analytic-verbal and Spatial

The mathematics education researcher Vadim Krutetskii (1976), working in the former Soviet Union during the 1950s and 1960s, used diagnostic interviews to investigate the way students worked with mathematics tasks. He found there were three kinds of mathematical reasoning. He called 'analytic' that kind which relied on words and chains of logical reasoning, which analysed a task into separate terms or symbols and concepts and subtasks and separate steps. He used the term 'synthetic' for the kind of thinking that involved images and spatial thinking (mentally working with mental images). A third kind of thinking, called 'harmonic' was a flexible combination of the other two kinds (Krutetskii 1976 p xiv). Many mathematics tasks can be handled in one or other of the three ways. Consider this: A boy says to his sister, 'If you give me 8 nuts then we will have an equal number'. But she replies, 'If you give me 8 nuts, I will have twice as many'. How many nuts did each have? (Krutetskii 1976 p 204). Do you use algebra (analytic) or a diagram (spatial) or some combination of these two methods?

John Munro suggests teachers should try to match the method of instruction to a student's preferred cognitive style (Munro 1995). It is also helpful to try to extend students, encouraging them to develop skills outside of their preferred cognitive style.

The idea that different people can have verbal abilities as well as non-verbal, in particular, spatial abilities, is very old. You may be good at music, and I may be good at mathematics, and our friend may be able to write sonnets without raising a sweat, while yet another friend is a wonderful sight on the ballroom floor. When the first intelligence tests were being developed, psychologists found it helpful to develop word-related and logical reasoning tests, and also to develop spatial pictorial tests, because they found that different people had different kinds of abilities. Psychologists needed different kinds of tests to be able to evaluate these different abilities. One test could not capture the whole variety of individual skill, talent, achievement, intelligence or, broadly, 'ability'.

It often happens that a student who seems to have average intelligence, or even lower than average intelligence, as shown by verbal intelligence scores or word-related achievement at academic school work, may actually have above average non-verbal intelligence, possibly of different kinds, including body actions—consider the body-intelligence of a skilled gymnast or dancer—or picture-making skill—how well can you draw a recognisable 'likeness' of another person, or even copy another picture? The recent discussion of multiple-intelligences (for example Gardner 1983) simply carries these psychological theories across into classroom applications, connected with ideas of personal cognitive styles.
Krutetskii's achievement, in part, is to identify very clearly the role of spatial and verbal thinking within the mathematics curriculum, and outline a theory of mathematics learning and thinking which parallels the familiar ideas of constructivism. According to Krutetskii many kinds of mathematics which may not seem at all spatial can actually be handled by spatial thinking, the inner or mental use of images as an alternative to overtly manipulating objects. But geometry, in particular, is a branch of mathematics that appears to rely on spatial thinking, even while it develops sophisticated analytic reasoning as part of its general intellectual tool kit.

Geometry is the formal study of spatial concepts such as 'point, line, plane, angle, turn, region, parallel, perpendicular, similarity' and 'congruence'. Spatial thinking is the broader ability to use mental images in spatial ways. Of course, ever since Descartes (and the other inventors of coordinate, that is algebraic Cartesian geometry) we have been able to express formal geometric concepts, such as Pythagoras's theorem about right-angled triangles, in formal algebraic ways, such as \( a^2 + b^2 = c^2 \), which readily generalises beyond geometric of everyday spatial interpretations to such hyper-dimensional equivalents as \( a^2 + b^2 + c^2 + d^2 = e^2 \). Some algebraic treatments of geometric situations, while elegant and direct, are far harder for students to deal with than the equivalent simple ideas related to obvious diagrams and spatial properties.

That is, we can dispense with a diagrammatic geometric treatment if we want to. But this makes the mathematics harder to learn. Similar remarks can be made about the differences between formalised or axiomatic treatments of geometry, and less formal approaches using rough sketches, approximate definitions, and spatial thinking.

Consider some examples that might help to show the connections, and differences between these different kinds of thinking. Consider any triangle ABC. Construct perpendicular bisectors of the sides AB, BC and AC. Using ordinary arguments of Euclidean geometry (in particular, arguments based on establishing the 'congruence' or geometric equivalence of pairs of triangles), prove that the three perpendicular bisectors intersect each other at a single point. Show also that this point is the centre of a circle which passes through points A, B and C, a circle that 'circumscribes' the triangle. Incidentally, do you know how to use a ruler, pencil and compass to construct a perpendicular bisector for any line AB? Can you provide Euclidean arguments (or vector arguments or transformational geometry arguments) to prove that the construction succeeds in making a line which both bisects and which is perpendicular to the line being bisected?

Having done this, can you now translate this situation into coordinate geometry? Let A be the point (0, 0) and B be the point (x, 0) and C be the point (m, n), where x, and n are both non-zero, and m is not equal to x. Use coordinate geometry arguments to show that the equations of the straight lines which pass through the mid-points of AB, BC and AC, which are also perpendicular to lines AB, BC and AC, intersect at one single point which is equi-distant from A, B and C (Gough 1994 p 1).

Similar investigations, Euclidean and Cartesian, can show that the angle-bisectors of the angles in any triangle meet at a point which is the centre of a circle which just touches the sides of the triangle (the inscribed-circle); the medians of any triangle...
intersect at a single point; and, the altitudes of the sides of a triangle also meet at a single point. Do you know how to use a ruler, pencil and compass to bisect any angle, or to construct a perpendicular to a line at any given point on the line? Do you know how to find the equation of a straight line which halves the angle between any other two distinct straight lines?

Sketch what the following diagram would look like when viewed from point A, point B, point C and, finally, Point D.

This, of course, is an adult equivalent of Piaget's three-mountain task. As you attempt any of these spatial thinking activities, you might like to consider where they might arise in a van Hiele developmental level, or in a Victorian Curriculum & Standards Frameworks (CSF 1995) Strand and Level. Also consider whether or not you are using school-learned skills to tackle these tasks.

Conclusions(?)

Finally, it is worth remembering, as a good devil's advocate will remind us, a key practical fact: learning, like thinking, is something that happens inside people's heads. Last year I made a similar point in discussing theories of constructivism. When a person learns, what is being 'constructed' is, literally, connections between brain cells. Something similar can be said about spatial thinking. Whatever the theories—Piaget's, Hughes, van Hiele's, Gardner's, or others—what really happens, in terms of working with physical objects, diagrams and mental images occurs inside brains. Perhaps Krutetskii's discussion of 'synthetic' thinking, or Gardner's 'spatial intelligence', what I have sketched here as spatial thinking, comes closest to anything which might actually correspond to changes in connections between brain cells. We may yet live to see a time when the brain's active functioning is mapped, and we will see that when a person solves a mathematics problem spatially this occurs in brain-location X, and when a person solves the problem with verbal-analytic methods this occurs in location Y. But I doubt any brain-locations will be identified with a Piagetian Developmental Stage or a van Hiele Level.

Of course being able to see where spatial thinking is located in the brain will tell us nothing, directly, about how to construct a spatial thinking curriculum, and is unlikely, short of inventing brain-hats that students will wear in class, to enable a teacher to know whether or not a curriculum is succeeding, and a student not only is thinking spatially, but is also learning, developing new spatial thinking skills and concepts. But careful, critical, constructive, sceptical analysis will help us understand our curriculum and our students better, and we will be able to teach more effectively. For me this is the purpose of research.
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Spiritual Knowledge and Intelligence

Beverly Jane — Faculty of Education: Monash University: Peninsula campus
John Gough — Deakin University: Education Faculty (SDS)

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Abstract
Following critical analysis of recent developments in Howard Gardner's theory of Multiple Intelligences, the authors became interested in the area of "spiritual knowledge" (an aspect of Gardner's "existential intelligence"). Critical reading of academic research literature, and of biography, autobiography and "literature" (including fiction, and poetry), provides a description and critique of "spiritual knowledge", while preparing for further research.

An Introductory Outline of a Research Methodology and Example
This discussion of Literature Reviewing as a research methodology, taking Spiritual Knowledge as a case-study of how the methodology is used, will:
- present a case for regarding "spirituality" or "spiritual experience, knowledge and intelligence" as an aspect of human existence, which is readily seen to vary amongst individuals;
- link the variations in different facets of human existence with Howard Gardner's theory of multiple intelligences;
- note possible overlap with EQ or "emotional intelligence" as considered by researchers such as Daniel Goleman, whereas Gardner’s theory subsumes EQ into several of his "multiple intelligences";
- explore the uncertainty regarding a Gardner-type approach to a possible "spiritual intelligence";
- use Gardner's original eight-point criteria for identifying and defining an "intelligence" as a basis for critique of the concept of "spiritual intelligence"; and
- finish with some samples from a "literature review", including a review of "Literature".

Recent interest in Spiritual knowledge or intelligence in science and technology education
It is becoming recognised more and more that the old mechanistic paradigm, with its Cartesian-Newtonian science, no longer serves us. As a result, many scholars are calling for a paradigm shift, including Capra and Australian scientist Charles Birch. Science educators favouring an ecological worldview include Smith (2001) and Jane (2001). Jane argues for a new paradigm, “deep ecology”, because it is holistic, and includes spiritual and subjective viewpoints, which offer the potential to contribute to a sustainable future for our planet.
Keirl (2002) critiques Howard Gardner’s Theory of Multiple Intelligences to see if MI theory relates to the domain of Design and Technology. MI theory better addresses the complex nature of the human mind and attempts to offer an holistic view of human intelligence. However we argue that MI theory falls short of providing a universal account of intelligences. In developing our argument we have been searching the literature: the first step of any purposeful journey is often the most important.

What is “Spiritual Knowledge”?
Mathematical knowledge includes examples such as $2 + 3 = 5$, or this two-dimensional geometric object, $\Delta$, is a “triangle”. Linguistic knowledge includes information about “parts of speech” such as “nouns”, and written letters of the alphabet, and their phonetic or spoken counterparts “phonemes”. Similar statements can indicate what “knowledge” means in the areas of music, art, history, and, moving away from “cognitive” or “intellectual knowledge” into other kinds or “performance knowledge” such as dance, sport, and vocational and recreational activities.

We can also extend any discussion of knowledge or experience to “emotional knowledge” such as understanding (usually through personal experience mixed with social discussion) emotions such as rage, envy, sympathy, dislike, hatred, and love, and related physiological states such as nausea, ecstasy and lust.

But if we want to discuss “spiritual knowledge” or “spiritual experience”, and want to argue that this is a form of knowledge or experience that is different from any of those already mentioned, what do we mean?

I believe that if someone really wants a happy life then it is very important to pursue both internal and external means; in other words, mental development and material development. One could also say “spiritual development”, but when I say “spiritual” I do not necessarily mean any kind of religious faith. When I use the word “spiritual” I mean basic human good qualities. These are: human affection, a sense of involvement, honesty, discipline and human intelligence properly guided by good motivation. We have all these qualities from birth; they do not come to us later in our lives. (The Dalai Lama’s Book of Wisdom, 1999, p 5.)

It needs to be stated, at the outset that spiritual knowledge has NOTHING to do with so called knowledge of god (or gods, or goddesses, minor deities, animist water-spirits and tree-spirits, or their demonic equivalents, such as Satan, Beelzebub, devils, or imps), angels, astral bodies, spirits, ghosts, bogles, afeets, djinns, vampires, werewolves, and other creatures of the occult. Nor has it anything to do with a so called “immortal soul” or with a non-physiological, non-emotional, non-intellectual “spirit”-component of a human. I am content to let others deal with matters of the paranormal.

We use the term “spiritual knowledge” to focus specifically on particular kinds of natural human experience and awareness which can be attested to by atheists, agnostics, and religious-believers alike, while omitting any consideration of the non-human, supra-human or supernatural.
Saints and sinners have always been with us. So have holy men, and holy women, priests, shamans, witch-doctors, medicine-men, witches and warlocks, monks and nuns, visionaries and prophets, and ordinary lay-people. Churches, temples, shrines, synagogues, cathedrals, sacred-sites and cemeteries. Icons, cult-objects, fetishes, juju, divining rods and bones, I–ching sticks and dice, Viking runes and casting sticks or bones, zodiacs and horoscopes, numerological computations. Leave aside reports of, and belief in the supernatural, in para-pschology, in the paranormal — tales of levitation, reincarnation, prophetic dreams that come true, numerology, telekinesis, poltergeists, astral travel, angels, demons, and the “soul” — and accept that things we can refer to as “spiritual” have always been part of human activity, whether we believe in any of it or not.

Wherever human activity exists there is human variation. Some people are physically stronger, some are weaker. Some are intellectually cleverer, some are slower or more limited in their ability to use their brains to solve problems. In the case of spiritual activities, it is easy to demonstrate that some people are more worldly, and others are less worldly, and, correspondingly, more concerned with matters we can describe as “spiritual”.

In some ways these spiritual matters overlap with philosophical issues of ethical behaviour. How should a person live? What is a good life? Why does evil exist? What, if anything apart from biological (physical or biochemical) finality of an organism, is the nature and meaning of death? What is life? What is consciousness?

Clearly, asking such questions also moves us away from “spiritual”, towards “scientific”, and “socio-political”.

Already in this preliminary discussion of the term spiritual knowledge we can envisage a conceptual or experiential spectrum that starts, at one scientifically demonstrable end, with certain kinds of brain functions that may be identified using highly sophisticated brain-imaging, and ranges to a mystical and almost incommunicable end, with human reports of religious belief, accounts of personal conversion to belief, and, in the extreme, even visions of supernatural beings or the experience of religious presence.

Non-Religious Aspects of Spiritual Knowledge

Our discussion will deal with the more demonstrable, communicable and less mystical aspects. These include, as examples, a sense of:

• awe: recognition of the largeness and complexity and power of the universe, at a cosmological scale, and at geological, biological, molecular, and even subatomic scales;

• humility: realistic awareness of an individual person’s human limits, finiteness, weakness, and comparative long-term and large-scale insignificance: this may be further extended, within the biological arena, by a non-species-ist acceptance of the equal value of non-human species;

• belonging: feeling at one with the universe: this may be experienced also as a profound sense of respect for the environment and its complexities, and subtly balanced forces;
• mystery: awareness of the limits of personal and collective intellectual knowledge, and the unresolvably conflicting alternatives;
• mortality: recognition and acceptance of one’s own death, and the death and eventual ending of everything currently known and experienced;
• responsibility: awareness of personal involvement in the universe, linked with a sense of conscience, and awareness of a larger balance and justice;
• uncertainty: awareness and acceptance of the inevitability of change, and randomness, and the accidental or arbitrary nature of events and existence;
• obedience: awareness of the need to conform to inexorable and unavoidable physical and social forces (or risk loss of one’s own liberty, or life, or risk doing damage to others or to the environment);
• aesthetic harmony: recognition that human existence includes more than food, shelter, time-passing, and biological drives.

We only need to consider human memories of such everyday experiences as looking at the stars in a clear sky, watching ocean waves crashing against rocky cliffs, seeing teeming microscopic planktonic life in a drop of sea-water shown in a TV documentary, glimpsing a rainbow at the tail-end of violent thunder-storm; or the twilight-darkness of a total solar eclipse — such evocative moments are more than intellectual, and emotional, more than mere electro-chemical perceptual data from the natural world.

Spiritual knowledge, glimpsed in childhood, can be life-changing. Albert Einstein is said to have begun his life-work as a scientist when he was given a simple magnetic compass, and the unchanging North-pointing of the compass-needle challenged his naïve child’s sense of the direct physical relationship between natural objects.

**Spiritual Knowledge &/or Intelligence(s): Howard Gardner’s Journey**

Analysing varieties of human activity, Howard Gardner proposed the idea of "multiple intelligences" (1983), highlighting that there is more to “intelligence” than a standard IQ test might be able to deal with. As we shall see, having begun with some of the more obvious kinds of intelligence (or human experience), Gardner’s theory has grown towards the general territory of spiritual knowledge.

Initially Gardner suggested **seven** different kinds of intelligence, categorized, briefly, as follows:

1. Visual-spatial or art smart: creative, imaginative, and perhaps more a visual learner;
2. Bodily-kinesthetic or body smart: agile, energetic, touching and talking healthily;
3. Logical-mathematical or math smart: logical, inventive, and a problem-solver;
4. Linguistic-verbal or word smart: reader, writer, and perhaps more an auditory learner;
5. Musical-rhythmic or music smart: sings, plays, and is rhythmic
6. Interpersonal or people smart: a socializer, a listener, and a keen communicator; and
7. Intrapersonal or 'me' smart: strong-willed, intuitive, and an introspective learner.

Later Gardner proposed an eighth intelligence:
8. Naturalistic or category smart: holistic thinker, classifier and appreciates the environment (e.g. Gardner 1999).

But what does it mean to be Naturalistically intelligent? Would we want to believe that a maritime culture that divides all sea creatures into two fish-related categories, namely “fish that I eat” and “fish that eat me”, is less Naturalistically intelligent than others whose sea-food recipes include bouillabaise?

Naturalist intelligence designates the human ability to discriminate among living things (plants, animals) as well as sensitivity to other features of the natural world (clouds, rock configurations). This ability was clearly of value in our evolutionary past as hunters, gatherers, and farmers; it continues to be central in such roles as botanist or chef. I also speculate that much of our consumer society exploits the naturalist intelligences, which can be mobilized in the discrimination among cars, sneakers, kinds of make-up, and the like. The kind of pattern recognition valued in certain of the sciences may also draw upon naturalist intelligence. (Cited in (Checkley 1997.)

This is particularly interesting because it is clear that Gardner is attempting to capture quite diverse forms of human experience in his search for other “intelligences”. More recently still, Gardner has been considering the possibility of a ninth intelligence, namely an “Existential” intelligence.

For example, in one interview Gardner explained:

In my efforts to update MI theory in the light of new research, I am considering the possibility of existential intelligence. This term denotes the human proclivity to ask fundamental questions about life:

Who are we?
Where do we come from?
Why do we die?

Certainly kids resonate to these questions, and such queries also form the basis of much of our religion, art, science, and philosophy. One of the entry points that I mentioned above is actually called the existential, or foundational, one.

It takes as its point of departure the posing of such big questions. I see my three topics as my own answer to three existential questions:

- Where do we come from? (Evolution is the only scientific answer to this question; there are, of course, faith-based answers.)
- What are some of the wonderful things of which humans are capable? (To my mind, the music of Mozart is as good an answer as any.)
- What are some of the terrible things of which humans are capable? (Alas, the Holocaust gave new meaning to the word evil.) (cited from Scherer 1999).

Already Gardner’s discussion of Existential Intelligence seems to overlap with broad aspects of spiritual knowledge.
In another interview Gardner adds:

We might say that existential intelligence allows us to know the invisible, outside world. The only reason I haven't given a seal of approval to the existential intelligence is that I don't think we have good brain evidence yet on its existence in the nervous system — one of the criteria for an intelligence. (Checkley 1997)


In chapters 4 and 5, Gardner considers several new candidate intelligences — spiritual, moral, existential, and naturalist — ultimately settling on only the latter two. While there is a good case to be made for spiritual intelligence, he observes, our capacity to grasp cosmic and transcendent truths ultimately depends on affective characteristics and we have as yet no scientifically reliable way of investigating such traits.

Moral intelligence is also rejected on the grounds that morality involves value judgments and intelligence is by nature value-neutral. (Robert Coles would disagree.)

Existential intelligence — the capacity to ask profound questions about the meaning of life and death — is one of the cornerstones of art, religion, and philosophy and qualifies as an intelligence in its own right, says Gardner.

However, since he has not been able to find the part of the brain dedicated to dealing with such questions, he is hesitant to add it to the list.

As for naturalist intelligence — the ability to recognize and classify natural species and understand ecological relationships — Gardner says that it deserves to be recognized as a bona fide intelligence, similar to the seven described in the original theory. [From a book review at http://www.scottlondon.com/reviews/gardner2.html last accessed 28 August 2002-08-28]

Another review of Gardner’s discussion in *Intelligence Reframed* adds this:

According to Howard Gardner (1999 p 59) there are problems, for example, around the ‘content’ of spiritual intelligence, its privileged but unsubstantiated claims with regard to truth value, ‘and the need for it to be partially identified through its effect on other people’. As a result:

It seems more responsible to carve out that area of spirituality closest ‘in spirit’ to the other intelligences and then, in the sympathetic manner applied to naturalist intelligence, ascertain how this candidate intelligence fares. In doing so, I think it best to put aside the term spiritual, with its manifest and problematic connotations, and to speak instead of an intelligence that explores the nature of existence in its multifarious guises. Thus, an explicit concern with spiritual or religious matters would be one variety — often the most important variety — of an existential intelligence.

Existential intelligence, a concern with “ultimate issues”, is, thus, the next possibility that Howard Gardner considers — and he argues that it “scores reasonably well on the criteria” (Gardner p 64).
However, empirical evidence is sparse — and although a ninth intelligence might be attractive, Howard Gardner is not disposed to add it to the list. “I find the phenomenon perplexing enough and the distance from the other intelligences vast enough to dictate prudence — at least for now” (Gardner p 66).

The final, and obvious, candidate for inclusion in Howard Gardner's list is “moral intelligence”. In his exploration, he begins by asking whether it is possible to delineate the “moral domain”. He suggests that it is difficult to come to any consensual definition, but argues that it is possible to come to an understanding that takes exploration forward. Central to a moral domain, Howard Gardner suggests, “is a concern with those rules, behaviours and attitudes that govern the sanctity of life — in particular, the sanctity of human life and, in many cases, the sanctity of any other living creatures and the world they inhabit” (Gardner p 70).

If we accept the existence of a moral realm is it them possible to speak of moral intelligence? If it “connotes the adoption of any specific moral code” then Howard Gardner does not find the term moral intelligence acceptable (Gardner p 75).

Furthermore, he argues, researchers and writers have not as yet “captured the essence of the moral domain as an instance of human intelligence” (Gardner p 76).

“As I construe it, the central component in the moral realm or domain is a sense of personal agency and personal stake, a realization that one has an irreducible role with respect to other people and that one's behaviour towards others must reflect the results of contextualized analysis and the exercise of one's will.... The fulfillment of key roles certainly requires a range of human intelligences - including personal, linguistic, logical and perhaps existential — but it is fundamentally a statement about the kind of person that has developed to be. It is not, in itself, an intelligence. 'Morality' is then properly a statement about personality, individuality, will, character — and, in the happiest cases, about the highest realization of human nature.” (Gardner p 77)

So it is, that Howard Gardner has added an eighth intelligence — naturalist intelligence — to his list. He has also opened the door to another possibility — especially that of existential intelligence — but the court is out on that one. [Mark Smith 2002, at http://www.infed.org/thinkers/gardner.htm]

What are these “criteria” that Mark Smith refers to, used to determine whether a proposed new intelligence deserves to be included in the collection of Gardner’s Multiple Intelligences?

In setting up his original theory with seven distinct intelligences, Gardner viewed intelligence as 'the capacity to solve problems or to fashion products that are valued in one or more cultural setting’ (Gardner & Hatch, 1989).

He reviewed the literature using eight criteria or 'signs' of an intelligence:
  • Potential isolation by brain damage.
In developing a clearer account of spiritual knowledge, it will be helpful to consider any evidence we already have that might indicate that some, at least, of Gardner’s eight criteria apply in the case of spiritual intelligence.

Consider, initially, an example of research on brain-function related to spiritual knowledge.

Religious belief and experience are usually regarded as beyond scientific exploration, yet neurologists at the University of California San Diego have located an area in the temporal lobe of the brain that appears to produce intense feelings of spiritual transcendence, combined with a sense of some mystical presence. Canadian neuroscientist Michael Persinger, of Laurentian University, has even managed to reproduce such feelings in otherwise unreligious people by stimulating this area.

According to Persinger:

‘Typically people report a presence. One time we had a strobe light going and this individual actually saw Christ in the strobe … [another] individual experienced God visiting her. Afterwards we looked at her EEG [electroencephalogram] and there was this classic spike and slow-wave seizure over the temporal lobe at the precise time of the experience — the other parts of the brain were normal,’

The fact that we seem to have a religious hot-spot wired into our brains does not necessarily prove that the spiritual dimension is merely the product of a particular flurry of electrical activity [in the brain]. After all, if God exists, it figures He [or She, or It] must have created us with some biological mechanism with which to apprehend Him [etc.]. (Rita Carter Mapping the Mind, 1998, pp. 13, 19: citing Ian Cotton “Dr Persinger’s God Machine” 1995.)

Other researchers report similar findings: Michael Shermer 2001; Andrew Newberg, Eugene D’Aquili and Vince Rause 2001; Cook and Persinger 1997; Saver and Rabin 1997; and Bob Holmes 2001.

Consider the following further examples:

• recent research on psychopathic criminals links an absence of functioning social and personal morality, that is, a “conscience”, with specific brain damage (e.g. Antonio Dimasio’s research on the behavioural effects of lesions in the orbital
frontal cortex — the so called “moral compass”, resulting in psychopathic consciencelessness: O’Neill 1999;
• biographical knowledge of saints, whose spiritual abilities are prodigious;
• an identifiable core of behaviours, including conscience, empathy, meditation, spiritual ecstasy or trance-like experiences;
• accounts of monastic, meditation, Zen, and other forms of spiritual training;
• by contrast, evolutionary (bio-genetic survival value) may be far harder to argue;
• supporting neuroscientific research on religious brain-states is known, for example Cook & Persinger (1997); and
• whether a spiritual symbol system exists may be harder to argue, but many spiritual practices include icons, and symbols of religious experience and belief, such as the figure of Jesus being crucified (and an abstract cross), and Tibetan mandalas, and Australian Aboriginal cave and sand-paintings and alcheringa designs.

Michael Shermer, citing the neurological research of Newberg et al., says: When Buddhist monks meditate and Franciscan nuns pray, for example, single positron emission computed tomography scans [PET scanning] of their brains indicate strikingly low activity in the posterior superior parietal lobe. The authors dub this bundle of neurons the orientation association area (OAA). The area’s primary function is to orient the body in physical space … when the OAA is up and running smoothly, there is a sharp distinction between self and non-self. When the OAA is in sleep mode — as in deep meditation and prayer — that divide breaks down and, consequently, the lines between reality and fantasy are blurred. Is this what happens to monks who feel a oneness with the universe or with nuns who feel the presence of God? (Shermer 2001, p 54).

The expression “losing oneself”, in relation to mystical experience, ecstatic trance, and similar moments of awe and insight, springs to mind. But it is important to realise that such experiences do not come easily. They usually require careful instruction, and practice. That is, they are a form of learned behaviour, partly conscious, and deliberated, and partly subconscious and intuitive.

However, as a means of gathering further evidence of spiritual intelligence, Literature Review may be a valuable first step, easier and cheaper than attempting either brain research or genetic and archaeological research. That is, surveying “literature”, or searching through published research journals (across several overlapping and related disciplines, such as anthropology, religion, and psychology), as well as searching Literature, the literary world of novels, plays, poems, and the related worlds of biography and autobiography.

A Literature Review of Literature Incorporating Spiritual Knowledge

Here is a first example: a transcendent feeling of “belonging”, of being part of the universe.

Arthur Koestler’s novel Darkness at Noon (one of the great documents of the Twentieth century) describes the last weeks in the life of a Communist terrorist and
radical during a 1930s Stalinist purge of party leaders and functionaries. Rubashov, a former Commissar, is imprisoned (not for the first time), and interrogated, before being subjected to a show-trial, and executed. (Koestler had himself been imprisoned by Franco’s fascists during the Spanish Civil War, so his account of prison life is chillingly convincing.) Shortly before his death, Rubashov’s interrogations have ceased, and he is left alone, untroubled by warders or interrogators. It should be noted, in passing, that as a devout Communist, Rubashov has abandoned any religious background he may have had during his pre-Revolutionary childhood, and is a confirmed atheist, believing only in Marxism’s dialectical materialism.

Sometimes [Rubashov] would respond unexpectedly to a tune, or even the memory of a tune, or of the folded hands of the Pieta, or of certain scenes of his childhood. As if a tuning fork had been struck, there would be answering vibrations, and once this had started a state would be produced which the mystics called ‘ecstasy’ and saints ‘contemplation’; the greatest and soberest of modern psychologists had recognised this state as a fact and called it the ‘oceanic sense’. And, indeed, one’s personality dissolved as a grain of salt in the sea; but at the same time the infinite sea seemed to be contained in the grain of salt. The grain could no longer be localised in time and space. It was a state in which though lost its direction and started to circle, like the compass needle at the magnetic pole; until it finally cut loose from its axis and travelled freely in space, like a bunch of light in the night; and until it seemed that all thoughts and sensations, even pain and joy itself, were only the spectrum lines of the same ray of light, disintegrating in the prism of consciousness. … Apparently even a patch of blue sky [glimpsed from his cell, or remembered from childhood] was enough to cause the ‘oceanic state’. (Koestler 1940, p 203).

Tragically, Rubashov is still trying to serve his Party, and its higher goals, even as the Party decides to destroy him. He realises, as he reflects on his new insights that “The ‘oceanic state’ was counter-revolutionary … [was] ‘escape from the task’, ‘desertion of the class struggle’” (p 204). He comes to believe that “for forty years he had been running amuck — the running-amuck of pure reason” (p 205).

Much of this could now be explained scientifically as Rubashov’s physiological and emotional response to physical torture, mental suffering, sleep-deprivation, starvation, isolation, and other destructive aspects of his imprisonment. But the insight he achieves is itself a form of learning, and exactly parallels that willingly sought by devotees of kinder belief systems.

Other possible books include:
- Ursula Le Guin *A Wizard of Earthsea* where the breaking of laws of creation which emphasise the importance of “balance” results in disruption and the release of evil;
- Ursula Le Guin *The Farthest Shore* where death is seen to be an essential aspect of human life and values.
Looking beyond books, occasionally films touch on aspects of human experience that can be described as spiritual. (This is discussed at length, with a special theological emphasis, by Robert K. Johnston’s *Reel Spirituality* 2000.)

Consider, for example, the popular films of the Australian director Peter Weir, such as *Picnic at Hanging Rock, and Dead Poet’s Society*. Images and attitudes that may initially strike the viewer as odd or disturbing, become more sensible if they are reconsidered as examples of spiritual knowledge.

In *Picnic at Hanging Rock*, otherwise unexplained, almost randomly inserted close-up shots of animals (a blue-tongue lizard, for example), and the frequent images of the monolithic rocks themselves, seeming to hang surrealistically against a vast slowly sweeping cloudscape, might at first be seen as little more than scene-setting. In fact the literal visual impact of the brooding rocks, shown in disturbing visual perspectives, is emotionally heightened by evocative pan-pipes on the soundtrack. But the larger significance of these images is their mystery, a luminous feeling of awe, the tension between trivial human endeavours and the power, teeming richness, and unpredictability of the natural world.

The moral core of *Dead Poet’s Society* is simultaneously one of embracing celebration of rich culture, enhanced by the existential injunction to SIEZE THE DAY! Although Weir is not usually considered a maker of religious films, consider his apocalyptic, mystical working of Australian Aboriginal beliefs in *The Last Wave*, the impact on a tough-minded New York cop of Amish values and life in *Witness*, and the man/god, illusion/reality, stage/world dualisms in *The Truman Show*, where the off-stage director can “cue the sun”! (Incidentally, Johnstone gives a detailed chapter to Weir, as a maker of religious films. But oddly, does not mention, as a possible precursor, Graham Greene, as novelist, film-script writer and writer of major filmed-novels such as *The Third Man, The Heart of the Matter, and The End of the Affair*.)

A very different, but equally profound non-religious spiritual experience reported in fiction occurs at the moment of “nausea” in Jean-Paul Sartre’s philosophical novel of the same name (*Nausea* 1938). The central character, sitting alone in a park, realises, with a powerful physical sense of nausea, that the natural world around him, like the world of human activity that includes him, could be utterly different, and could change, irrationally, and arbitrarily, at any moment. Nothing that is necessary drives the world, its objects and events. Humans live in a terrifying world of change and freedom, where wildly different choices are possible. Yet despite being visited occasionally by this disturbing insight of “absurdity”, the Sartrean central character manages to find a way of choosing to BE, as a person, which convinces him that what he is doing is reasonable — as “reasonable” as anything can be in a world of chaos and choice.

Sartre’s colleague in existentialism, Albert Camus, in his philosophical novel *The Plague* (1947) provides an even stronger, less mystical, WAY for humans to live, in an absurd world, where everyone will, eventually, die, and human suffering (as Buddha recognised) is unavoidable. For Camus, living in an absurd, godless, material, finite world, the preferred way for a human being to live with dignity is to act to alleviate suffering, despite the fact that all such actions — like those of a doctor ministering to a patient — are doomed to end in failure. The patient may be helped to
live, for now, but will sooner or later die. Nonetheless the doctor persists in his forlorn, existentially absurd ministrations.

In an uncertain world, living in changing times, we can learn much about spiritual actions by reading novels. Consider, as a sprinkling of possible authors, Graham Greene, Elizabeth Goudge, Rumer Godden, Ursula Le Guin, and others.

**Conclusion, or Tentative Beginnings?**

There are no easy answers to questions about spiritual knowledge, intelligence, and learning, nor even clear directions. But like other aspects of human experience, the challenge for researchers is to investigate in any way possible.

We are reasonably familiar with modern technological Western culture, its materialism, and its emphasis on laboratory-objectified science as THE way of researching and establishing new knowledge. Its extreme aspects of would-be objectivity, the distinction between mind and matter, the distinction between living organisms and dead inanimate matter, its separation of human life from non-human life-forms are known, and have been criticised and questioned. Nonetheless Western science clearly has already begun to explore spiritual knowledge. Other ways of knowing, and other cultures also contribute to this project, including native American and Australian Aboriginal traditional cultures, with their blending of human and non-human life, their totem identification of people with animals, their grounding of humanity and culture in a whole environment.

The first step, beyond this discussion, will be to continue extending this initial sketch of a literature survey. Then we will know more, and be better informed about possible ways to progress.

**References and Further Reading**


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*The Constructivist Classroom* Volume 57 Number 3 November 1999

http://www.ascd.org/readingroom/edlead/9911/scherer2.html
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What is Spiritual Knowledge or Experience?

I believe that if someone really wants a happy life then it is very important to pursue both internal and external means; in other words, mental development and material development. One could also say “spiritual development”, but when I say “spiritual” I do not necessarily mean any kind of religious faith. When I use the word “spiritual” I mean basic human good qualities. These are: human affection, a sense of involvement, honesty, discipline and human intelligence properly guided by good motivation. We have all these qualities from birth; they do not come to us later in our lives.

*The Dalai Lama’s Book of Wisdom, 1999, p 5*

Mathematical knowledge includes examples such as $2 + 3 = 5$, or this $\Delta$ is a “triangle”. Linguistic knowledge includes information about “parts of speech” such as “nouns”, and written letters of the alphabet, and their phonetic or spoken counterparts “phonemes”. Similar statements can indicate what “knowledge” means in the areas of music, art, history, and, moving away from “cognitive” or “intellectual knowledge” into other kinds or “performance knowledge” such as dance, sport, and vocational and recreational activities. We can also extend any discussion of knowledge or experience to “emotional knowledge” such as understanding (usually through personal experience mixed with social discussion) emotions such as rage, envy, sympathy, dislike, hatred, and love, and related physiological states such as nausea, ecstasy and lust.

But if we want to discuss “spiritual knowledge” or “spiritual experience”, and want to argue that this is a form of knowledge or experience that is different from any of those already mentioned, what do we mean?

Let me state, at the outset, that, as far as I am concerned, this has NOTHING to do with so called knowledge of god (or gods, or goddesses, minor deities, animist water-spirits and tree-spirits, or their demonic equivalents, such as Satan, Beelzebub, devils, or imps), angels, astral bodies, spirits, ghosts, bogles, aferets, djinns, vampires, werewolves, and other creatures of the occult. Nor has it anything to do with a so called “immortal soul” or with a non-physiological, non-emotional, non-intellectual “spirit”-component of a human. I am content to let others deal with matters of the paranormal.

Although I may be guilty of abusing the word-stem “spirit”, or the usual church-cum-religious connotations in the word “spiritual”, I want to focus specifically on particular kinds of natural human experience and awareness which can be attested to by atheists, agnostics, and religious-believers alike, while omitting any consideration of the non-human, supra-human or supernatural.

Here is a first example: a transcendent feeling of “belonging”, of being part of the universe.

*Arthur Koestler’s novel Darkness at Noon (one of the great documents of the Twentieth century) describes the last weeks in the life of a Communist terrorist and radical during a 1930s Stalinist purge of party leaders and functionaries. Rubashov, a former Commissar, is imprisoned (not for the first time), and interrogated, before*
being subjected to a show-trial, and executed. (Koestler had himself been imprisoned by Franco’s fascists during the Spanish Civil War, so his account of prison life is chillingly convincing.) Shortly before his death, Rubashov’s interrogations have ceased, and he is left alone, untroubled by warders or interrogators. It should be noted, in passing, that as a devout Communist, Rubashov has abandoned any religious background he may have had during his pre-Revolutionary childhood, and is a confirmed atheist, believing only in Marxism’s dialectical materialism.

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References and Further Reading


Facing Our Own Death: A Secular Approach to a Spiritual Angst

I am going to die. You are going to die, too. You could bet on it. This is a safe bet. In the not so cynical words of … (?): “Only two things in life are certain: death and taxes.” Some people avoid paying taxes. Nobody avoids death. (But, in the words of the Monty Python sketch, “Nobody expects the Spanish Inquisition”.)

The young child wakes in the night, sobbing, “I don’t want to die”.
The concerned parent goes to the child and says:
A. Don’t worry, dear. You aren’t going to die.
B. Don’t worry, dear. You aren’t going to die yet.
C. Don’t worry, dear. You aren’t going to die now.
D. Don’t worry, dear. You aren’t going to die now, as long as terrorists, accidental house-fire or psychopathic arson; God-blasted lightning or meteorological incident such as hurricane, tornado, deluge, or flash-flood, plate-tectonic events such as an earthquake or volcanic eruption; the sudden impact of a meteor or asteroid or other cosmic debris or errant man-made satellite, faulty passing aeroplane or speeding road vehicle; … (etc.), doesn’t get you, suddenly.
E. Don’t worry, dear. We’re all going to die, sooner or later.
F. Don’t worry, dear. You’re right. You’re going to die. Get used to it.

And so on.

Aidan Chambers in his experimental Young Adult novel Now I Know (1987) presents this experience strikingly:

One evening, Nicholas Christopher Frome was lying idly in his bath when the thought struck him that eventually he would die. He had if course thought this before. His is no fool. But that evening it penetrated his consciousness with a terrible clarity. A clarity so pure, so undeniable that, despite the pleasant heat of the water, he turned cold inside. What made the thought so terrible was not the knowledge of his eventual death, but the realization of the separateness of his being. He was not, he understood completely for the first time, merely his parents’ son, nor just any seventeen-and-one-month year old youth, nor simply another member of the multitudinous human race. He was him self. A separate, individual, unique and self-knowing person who would one day snuff it. I am not, he thought, anyone else. Only me. … and one day this Me will come to an end. I shall not be. His stomach curdled. He sat up and spewed into his bathwater.

(Chambers 1987 p 9: emphasis in the original; ellipsis JG).

The Church of England’s Book of Common Prayer (1549) expresses a similar sense of shocked dread in its rites “At the Burial of the Dead”, particularly the prayer at the interment of the body:

Man that is born of woman hath but a short time to live, and is full of misery. He cometh up, and is cut down, like a flower; he fleeth as it were a shadow, and never continueth in one stay. In the midst of life
we are in death: of whom may we seek for succour, but of thee, O Lord, who for our sins are justly displeased. Yet, O Lord … O Holy and most merciful Saviour, deliver us not into the bitter pains of eternal death. Thou knowest, Lord, the secrets of our hearts; shut not thy merciful ears to our prayer; but spare us, Lord … suffer us not, at our last hour, for any pains of death, to fall from thee.

Here, apart from the moral issue of sins, and possible eternal damnation, the fact of mortality, and the eternity of death, and the agony of the individuality and solitariness of each death, weigh on the minds of the mourners attending the last journey of the person being buried.

The existential question, confronted with awareness of “personal mortality” is, to begin with, what are we going to do about it?
A. Deny it?
B. Ignore it?
C. Try to avoid it?
D. Enjoy what limited life we have as well as we can?
E. Use our available life in ways we choose, and are able, to live a “good” life?

A further existential question, closely related, arises from the death-related concept of “personal oblivion”. Not only is it a biological fact, an inevitability, that we are all going to die, we will all, in time, be utterly forgotten.

You might be as famous, for example, as your great-great-grandfather, who has (probably) ended up being utterly unknown even by his great-great-grandchildren. (If this example happens to fail in your case, and in fact your own great-great-grandfather actually was amazingly famous just add a few greats, and oblivion rears its blank head.)

You might be as famous as the President of the United States of America, or one of the Twentieth century’s film star icons. But just wait. There was a time when the United States of America did not exist. Like people, national organisations, and any aspect of human culture, has a finite life-span. In time, there will be no United States of America. All it takes is a nuclear holocaust, or an asteroid strike, or simply the passing of sufficient time for continents to move across the surface of the Earth, colliding, upheaving and subducting, and even “North America” changes into something else.

If geological changes to not bring about oblivion, be assured that the Sun will, in a few million years, use up its helium resources and turn into a Red Giant, and expand so far that it engulfs the Earth, or whatever remains of the Earth. You might take comfort in the idea of humans travelling to other, safer, so far surviving Solar Systems in our own Milky Way galaxy, or even to other galaxies. But if our historical descendants go far enough away from us, sooner or later personal fame will dwindle, and eventually reach the dwindled stage of oblivion. Just wait. You too will be utterly forgotten.

So, if you believe that the point of being alive, or a redeeming, or sustaining aspect of our awareness of our own mortality is that at least we will have made our mark, somehow, and not lived in vain, and we will, at least be remembered, think again.
This can only be true, it can only sustain you, in the near future. Further away in time
you will be anonymous dust.

Interestingly, our human awareness of death seems to be paralleled in some other
species.

For example, elephants seem to grieve when one of their social group dies. Consider
Derek Joubert’s *National Geographic* video *Reflections on Elephants* (1994).
Similarly Joyce Poole discusses elephants’ mourning (Poole 1996: also George Page
1999.)

Consider also chimpanzees, as discussed in a PBS web-site on animal intelligence,
emotions and consciousness:
http://www.pbs.org/wnet/nature/animalmind/consciousness.html
Chimps and elephants appear to exhibit another consciousness
trademark: an awareness of death. Both animals grieve when family
members die: elephants even linger over the bones of long-dead
relatives, seeming to ponder the past and their own future. (PBS
*Nature's Inside Animal Mind: "Animal Consciousness"*, October 23,
2001.)

**References and Further Reading**
Research as Archival Archaeology and Conservation: The Case of the Book on Learning Without ‘Learning’ in its Index!

Research typically looks forward, and privileges the new, while kicking aside older material. However, again and again the wheel is reinvented by researchers with forwards-only blinkers (or gear-boxes?). In 1984 Robert B. Davis published Learning Mathematics: The Cognitive Science Approach, a rich and powerful discussion drawing on years of curriculum development, classroom research, and mathematics education and information processing research. In 1999 Elizabeth Fennema and Thomas A. Romberg dedicated Mathematics Classrooms That Promote Understanding to the memory of Robert Davis. But he and his work do not appear in this book, or in other leading accounts of research in mathematics education and in school and university classrooms. What a loss! What an oversight! Hold fast that which is good. We need intellectual conservation to protect the endangered world of information as much as we need ecological conservation in defence of our biosphere.


New is Better, Righter — Old is Out-Dated, Wronger — Really?

Our culture is dominated by the relentless rush forwards, the pursuit of “progress”, and the uncritically accepted idea of scientific development, that new knowledge replaces old knowledge. We see this in the ever-changing fields of visual arts, where a new artist must NOT be like Picasso or Warhol or anyone earlier, but must be wholly new. The vicious word “pastiche” is sometimes used to target those whose art-style is judged to be derivative of another identifiable artist or art movement. (Despite this, art, and also music, and fashion in clothes and home decoration, may hanker after the old. In this case we can call the deliberately not-so-new “RETRO”, or “NEO-whateverperiod”, or give it critical approval by calling it a “Classic”. Nostalgia can have cachet, or can be chic. But, such aberrations aside, if it ain’t new it’s obsolete.)

We routinely expect that ideas, and practices have use-by dates, or sunset-clauses indelibly stamped on them. A change is as good as a holiday. The new broom sweeps clean. The old grey mare she ain’t what she used to be. And so on.

Other cultures are not like this. Confusian culture has a respect for the established traditions. A sound Confusian education is NOT up-with-the-latest, but case-hardened rigorously tempered drilling in standard dicta, routine arguments, and well rehearsed practices.

Similarly, the study of, literally, the Classics, is constrained by the fact that (barring the hoped for, but unexpected discovery of a lost or hitherto unknown work)
there are no new works of literature in Ancient Greek or Latin, no new Parthenons or Venus de Miloses — nor new Egyptian hieroglyphics, or Babylonian mud tablets. Archaeologists may discover new examples (previously LOST examples, or hitherto UNKNOWN) from past eras. But no live Caesar is writing his or her memoirs. No Sargon is dictating legal instructions to satraps in Bactria.

Certainly those who research the Classics may borrow from modern, new theories, to extend and modify their analyses of the past. Feminism, for example, or neo-Marxist workingclass perspectives, or Levi-Straussian structuralism, or Saussurian semiotics may be added to the Classicists’ tool-kit. But if new theories and research tools are brought into this field of research, the new research results must be fitted meaningfully alongside what is already established.

In these unusual cases, few babies are tossed out with bathwater.

In most other aspects of modern culture, and especially in educational research, we lose a lot of aging, well-washed babies!

Those of us engaged in teaching at tertiary levels are pressured to be at the cutting-edge. We may be sued if we claim to be providing effective instruction for contemporary needs, and are not in simply demonstrable ways “up-to-date”. We look at out textbook reading lists (“textbooks”! — shock! and horror! shock? horror? maybe! maybe not?) and agonise if they are (as I write) older than, say, 1995. Tut, tut! Dear me. This can hardly be a good resource book for preparing student-teachers to teach Primary school mathematics in the Twenty-first century (!), if the publication date is 1994, or, more shockingly, 1984! Tempus fugit, and the times they are always a-changin’!

I want to argue against this. I want to urge caution. I present this as a rearward-looking research methodology.

WHAT is this subject (whatever we are researching) about?
WHERE did it come from?
WHAT is its history, and WHAT can we NOW usefully learn from its PAST?

Old Theories Never Die, the Young Ones Just Act as Though They Had

It is unrealistic to ignore changes in theories. But that does not mean we should accept any new jumped-up Johnny-come-lately idea just because it is new.

Constructivism may be flavour of the month, or may have been, but that doesn’t mean that Behaviourism, or Gestalt theories go away, or that they ought to. We can critique Behaviourism until the cows come home, but humans still stubbornly go on ‘behaving’. Similarly the would-be scientific objectivity of Behaviorism continues to be relevant to educational research.

As hard science advances (yes, it does), we find that Biology becomes an essential aspect of educational theory. The continuing developments in scientific understanding of brain functions provide new ways of understanding what children are doing in schools, and the way adults think. (E.g. Butterworth 1999, Carter 1998, Dehaene 1997, and Greenfield 1997, and 2000). Where previously psychologists such as Richard Skemp talked, hypothetically about “ideas”, “concepts”, and “schemata” (e.g. Skemp 1971), neurologists can now identify small sections of the brain that become observably active when a person thinks of a word, or speaks the word, or hears the word, or writes the word.
This year genetic scientists identified a gene for language. People who do not have this gene, or whose version of this gene is defective, find it extremely difficult to acquire spoken (or other) language! In time we may have gene therapy that might reverse this. Until then, language deficits due to a faulty gene will be incurable, although diagnosable. Moreover, just as language deficits NOT due to brain damage are now diagnosable, so will gene defects be able to be eliminated as suspected culprits. (E.g. Gough 2001a, Smith 2001.)

At a much lower level of would-be science, the once popular theory of Benjamin Bloom’s Taxonomy of Cognitive and Affective Domains (e.g. Bloom et al. 1956), later discarded and discredited, returns, disguised in the shape of “learning outcomes” as in the now standard, and largely unquestioned (but NOT unquestionable) Curriculum and Standards Frameworks (1994, 1999, 2000) of Victoria. The wheel turns, bumps, wobbles, falls over, and returns.

We might look at a theory, such as “constructivism”, and slap our heads in wonderment, proclaiming that “This says nothing about the social context”, or “This ignores human interactions”, or “What about the different effect of tools on thinking?”, and then latch onto “social constructivism”, or “constructionism”. How could we have been so short-sighted?! Thank goodness we can throw MERE “constructivism” in the bin, and replace it, with many sighs of relief, with a suitable, vitamin-enriched “post-modernist-constructi-whatsit”. What about dispensing with “constructi-anything” altogether, and grab hold of “enactivism”, or “activity theory”, or “psychosociosemiotics”, or “situated cognition”, for example?

The last, as a viable concept, is rather silly. After all, “situated cognition” is what we have been talking about all along. In what possible sense were we ever talking about NON-SITUTATED cognition? Nonsense! Any talk of cognition always situated the cognising in some way, surely. Any change of name, or change of theory is only a change of emphasis.

Instead of situating our discussion of learning exclusively in the formal institutions of learning (schools, universities, and so on), we also consider learning and school-like behaviours in the work-place, and in such everyday situations as shopping, cooking, and holidaying. But are these so different? Didn’t school lessons also consider, for example, the mathematics of shopping, travelling, working, and other non-school and post-school situations? Do we really achieve anything importantly new by changing the terminology?

The same comment applies more generally to other theories, and the historical evolution and adoption of theories. If we regard language as a “tool”, then any discussion of learning that includes language-use (and this can include gestural languages such as American Sign Language, and so called non-verbal “languages” such as facial expressions and postural body language) necessarily entails some form of tool-use, and hence is actually some form of “constructionism”. Similarly, regarding the alphabet (or Chinese characters, and other forms of writing) as “technology”, any theory of written-verbal learning is necessarily a theory that includes the impact of technology on the thinking and behaviour of the human subject.
The Times May Be A-Changin’ But the Kids are Much the Same, etc.

Leaving aside the argument that old theories retain valuable ideas, and may, indeed reappear in modified and unsuspected forms, it is also true that, however theories may change, or appear to change, when the research focus is education or instruction or learning, much of the subject being considered by the theories remains largely unchanged. A child in a school is a child in a school. A student learning Primary school mathematics is still learning Primary school mathematics. What Rambella learns today is usually similar to what Rambella’s parents learned, and Rambella’s grandparents, and so on — back to everyday informal learning in medieval European villages, or wherever Rambella’s ancestors came from.

Even the wilder versions of the so called New Mathematics of the 1950s and 1960s, with its various emphases on axiomatic approaches, set theory, logical rigour, and abstract mathematical structure, possibly tricked out with colorful Cuisenaire rods, or Zoltan Dienes’ plastic attribute blocks, led, eventually, to students learning how to count, add, subtract, multiply and divide, learning how to solve quadratic equations, and, in short, learning a re-expressed version of the same kind of mathematics that Isaac Newton, or Mrs Samuel Pepys learned centuries earlier.

New post-modernist definitions of terms such as “literacy” may come into vogue, expanding on the old-fashioned Readin’ and ‘Ritin’, to allow for the “reading” of such new kinds of un-book-like “texts” as film, interactive web-pages, multimedia CD-ROMs, hypertext electronic “books” and Internet web-sites, spreadsheet tables, interrogatable databases, computer-animated graphs, and zoomable maps. But before students approach these dizzy heights, or perhaps simultaneously with some of the less alphabetically-demanding aspects of these new-fangled “texts”, students still need to learn their old-fashioned ABC.

Reading and Writing are still fundamental parts of “literacy”, deconstruct and reconstruct or post-modernise the term however you will. Hence the research methods and results of the 1960s and 1970s psycholinguists remain just as important as they ever were. (For example, Frank Smith 1971, 1973, 1975.) We throw this bathwater, and these babies, away at our peril. The technologies of the alphabet, and writing by hand, as well as by computer keyboard, remain as important as ever, technologise it however we like, even to the extent of developing computer-based voice-recognition, and the possibility of saying aloud whatever we want to communicate, instead of laboriously writing, letter by letter, or typing, letter by letter. (For example, Chandler and Gough 1999, and Gough 2000.)

Every Theory Has a History

As new theories come along we learn the new technical terms, the new jargon. As we learn to speak and use this new language, we are simultaneously learning a new way of understanding the world and the doing of research. (Language is a way of structuring, and making sense of otherwise raw perceptual experience of our physical world. But the links between language, language use, and the understood nature of the “world” or so called “reality” are philosophically subtle in the extreme: Gough 1997.)

For example, when Richard Skemp wrote his epochal book *The Psychology of Learning Mathematics* (1971), suddenly ordinary school mathematics teachers were expected to tune into Skemp’s new language of “concepts” and “schemas” (e.g. 1971
chapter 2 “The Formation of Mathematical Concepts” and Chapter 3 “The Idea of a Schema”). Having considered “the formation of single concepts”, we are told that, “each of these [single concepts] by their very nature is embedded in a structure of other concepts” (Chapter 3, p 37).

Then we strike Greek: “The general psychological term for a mental structure is a schema. The term includes not only the complex conceptual structures of mathematics, but relatively simple structures which coordinate sensori-motor activity” (Chapter 3 p 39).

Apparently Skemp regards learning to walk, or to dance a polka, as “relatively simple”, but I will pass over that with little further comment. Parents watching their baby progress from crawling to toddling know some of the complexities of what is achieved by upright bipedal locomotion, even though they have no first-hand recall of the difficulties they, too, overcame when they were infants. Dance students, similarly, know better than to underestimate sensori-motor learning.

Gosh! we might say. I thought I understood how we “know” or “learn” mathematics. But now I realise that there are “concepts” (single bits, like atoms or grains of mental sand) and “schemas” (which are collections or structures of “concepts” — mental molecules, or sandcastles, maybe). How new. How different. How difficult.

But, in fact, how not so new, at all. Herbert Read (1943 p 120) notes that James Sully (1896, pp. 352-353) is the first, as far as Read is aware, to use the term “schema” in this way. Decades earlier than Skemp, and before Piaget, from whom Skemp has silently borrowed the term.

Also, how potentially misleading. How lightly Skemp speaks of “mental”. However he is not actually referring to the interactions between brain cells when he speaks of “mental”. These days, thanks to neuroscience, we can actually use brain-imaging to show where in the head the “ideas” are, and also show how one brain-centre is linked with another, as the brain combines this bit (such as numerosity, the recognition of the quantity of objects we are considering) with that bit (such as the verbal term, or number word, for this particular numerosity), while also recognising this kind of object (such as a collection of playing cards), along with other features (such as size, color, position, and so on).

As a very different example, consider that Willatts, in 1977, and Morley in 1975, outline developmental stages by which children learn to draw objects on a kitchen table (Willatts’ drawing task) and a person (Morley’s drawing task). With sighs of relief we can now take up the results of this research, and Willat’s and Morley’s associated developmental theories, and totally reconsider how we will teach children to draw — or perhaps even whether or not we will try to teach them at all.

Maybe we will just show them lots of ways of drawing tables and people, and let the students make whatever sense of this experience they can. Would that constitute up-to-date constructivist teaching?

But in fact as early as 1922 Cyril Burt (he of the famous faking of twins-research data, but nevertheless a major serious educational research pioneer who made enormous contributions to education) published a seven-stage developmental outline of how children draw (Burt 1922 pp. 319-322: cited in Read 1943 p 117). All subsequent research has largely either rediscovered what Burt already knew, or totally
ignores Burt’s research, and anyone else’s research as well (e.g. Goodnow’s account of children’s drawing, how they learn it, and how difficult it is to change the way they do it by direct instruction, contains no mention of any of the classic developmental stages of children’s drawing: 1977).

We may think we are looking at something new. But the actual history may be concealed, or ignored, or the creator of the new theory may simply not know the earlier work — alas!

**Rationale for a Theory-Scanning Rear-View Mirror, or for an Archaeological Approach to Archives**

The preceding remarks are offered as a case for being aware of the history of theories, and their evolution. It is also further evidence for my arguments that we need continual vigilance, such as a devil’s advocate approach to any theory (Gough 1998), and constructive sceptical critique of any theory (Gough 2000).

All of this then leads to a small case study: the surprising neglect of Robert Davis.

**Case Study: Robert Davis and the “Cognitive Science Approach”**

Robert B. Davis’s *Learning Mathematics: The Cognitive Science Approach to Mathematics Education* (Croom Helm, London, 1984) summarises decades of mathematics curriculum development, research, and instructional innovation. Davis pioneered the Madison Project in 1957, one of many New Math experiments — arguably, one of the best. Davis is one of the great teachers, such as W.W. Sawyer, with research linked directly with our standard curriculum, at all levels! But his work is not widely known. Why?

Around 1984 the buzz-word “constructivism” swept in. Davis’s term “cognitive science” means the same thing, if “constructivism” means anything. Davis was aware of the new term (e.g. pp 338, 92), but it is neither prominent nor Indexed! Despite the prominent word “learning” in the title, most of his discussion is about “problem solving”, which IS his theory of learning! Hmm!

Through much of his discussion Davis draws carefully on several areas of research from the 1970s and earlier, particularly:

- information processing (the handling of information, including theories of human perception and thought);
- computer programming (especially Seymour Papert’s Logo programming language);
- artificial intelligence (the attempt to program a computer to simulate human intelligence);
- Piagetian theories such as “assimilation” and “accommodation”;
- mathematical problem solving;
- remedial mathematics and error analysis;
- mathematics learning, and mathematics performance (observed classroom behaviours);
• Piaget’s clinical interview method, and protocol analysis (working out the meaning of the recorded interactions between teacher, student, instructional materials, and task attempts;
• brain damage research; and
• latency studies (examining how long a person takes to handle individual steps in a multi-step task).

It is a heady, but remarkably powerful mixture, not always clearly flowing in its arguments, but always stimulating.

But Davis was in other ways ahead of his time.

His discussion also includes an early version of Jean Lave’s pioneering theory of “situated cognition” (Davis pp. 159-160: Lave 1982, and Lave, Murtaugh and de la Rocha 1984). Davis may have been one of the first to recognise the importance of Lave’s work. Yet it is typical of Davis’s eclectic and syncretist work that he was willing to draw on any useful research, and useful theory, any examples of real learning, not just in mathematics but also physics, music, reading and language use.

Robert Davis’s work is frankly eclectic. He borrows where and when he see fit. Sometimes this means that what he understands, and knows how to use, may outstrip the ability of his possible readers to follow his arguments. He is, simply, a polymath, able to see connections in sometimes surprising places.

To be able to understand Davis you need to be familiar with Piaget’s theory, information processing theory, artificial intelligence, computer programming, oral language acquisition theory, Chomsky’s theory of grammatical structures, undergraduate level mathematics, undergraduate level physics, education research, psychological research, … and so on.

What are some of his outstanding contributions?

Firstly, he reshaped Piaget’s well known clinical interview technique.

Interestingly, Piaget’s method may owe something to the very early research methodology of William A. Brownell, who simply asked students to “work their problems out loud” (Brownell 1928: cited in Leder and Forgasz 1992 p 4). Brownell was working, broadly speaking, within Thorndyke’s behaviorally oriented “associationist” approach. But he also emphasised the mathematical patterns and meanings that were shared by the drill-and-practice instructional materials used by associationists, and all drill-and-practice teachers.

One teacher-cum-researcher, and one student: the teacher-researcher observing, and encouraging, while the student negotiates a possible path towards a solution to a problem.’

But Piaget’s tasks were usually abstract, unusual, and different from ordinary school curriculum — albeit ingenious and often intellectually challenging.

By contrast, Davis’s discussion, again and again, focuses on the students’ grappling with otherwise ordinary school curriculum tasks: additions, solving equations, manipulating geometric objects.

The research methodology of audio or video recording student problem solving activity, and then analysing the student’s actions is Davis’s “protocol analysis”. This was pioneered in his long case study of students, from the start of schooling through to university levels, part of the Madison Project of the 1950s and later. Certainly
Davis was not alone in developing Piaget’s interview techniques in this way. But he was amongst the earliest to do so.

Secondly, Davis focussed on the actual learning, both when it was succeeding, and also, and extremely importantly, when it wasn’t succeeding. This meant that he was one of the first researchers to focus on student errors, and in particular, on those special kinds of errors that most students make, and those kinds that are peculiarly resistant to remedial intervention. Knowing that learning was a process of creating and modifying problem solving methods, he was especially interested when the usual problem solving strategies, the attempts to create a new solution, led to wrong answers — not just slips, but profoundly misconceived outcomes, that were stubbornly believed in by the students who created them.

Similarly, in directing attention to “errors” or “miscues”, Davis was introducing the then recently established methods of “miscue analysis” that had been devised in the psycholinguistic theories about the process of reading (e.g. Smith 1971, 1973, 1975, 1978). Such errors, or miscues provide not merely diagnostic information about what is going WRONG, but crucially important information about what a student is actually DOING! This provides invaluable insight into what the student is THINKING, and MIS-THINKING!

Much more recently, in upper Secondary mathematics, some of Davis’s “classic learning errors” in algebra have been studied by researchers such as Swedosh (1996) and Barrington (1997). The remedial breakthroughs reported at that time, and later, by Swedosh (1997), follow directly from Davis’s much earlier work.

Nowadays, especially in science education, we are familiar with the constructivist notion of “alternative conceptions”. But Davis highlighted these before they were called “constructivist”, or graced with the term “alternative conception”. He, and others, referred to them as “disaster studies”. Davis was particularly concerned to investigate what goes wrong with learning when students, and even highly trained supposedly “expert” mathematics and science professionals, are given comparatively simple mathematics or physics questions, and come up with shockingly wrong answers. Aristotelian, friction-based pre-Newtonian conceptions of dynamics die hard, and so called everyday common sense prevents the correct application of highly trained principles!

Again, in important ways, this attention to “expert” behaviour provided invaluable insight into “student” behaviour, and hence the way teachers could more effectively interact with student, strengthening their learning. This paralleled the research of psycholinguists who were trying to understand how to help students learn to read (for example, Frank Smith, again: 1971, 1975, 1978; also Paul Kolers, and others, assembled in Smith 1973). When psycholinguists observed what competent (“expert”) readers actually do, they discovered “errors” that were better regarded as “meaningful miscues”, where letters and words were sometimes mis-read, but, typically, resulted in alternative and acceptable meanings. When a miscue resulted in a non-acceptable interpretation of the text being read, the expert saw cued to re-read and attempt to self-correct. (You may have done this yourself in the preceding sentence when you encountered the misleading typographical reversed-letter-order rendering of “saw” instead of “was” — or didn’t you notice it? Typically, “expert”
readers predict so much of what they are reading that a strong prediction obviates the need to attend to each word, or each letter.)

Thirdly Davis expanded Polya’s simple four-stage view of problem solving (namely Look, Plan, Do, and Check: Polya 1945, Part 1, point 6, pages 5-6), not exclusively in mathematics, into seven or more steps. In doing this Davis was drawing on both neurological research, and the parallel investigation of computer programming and “artificial intelligence”, linked with the psychological theory of “information processing”.

(1) Examine the problem (or input data);
(2) Retrieve from memory some knowledge representation structure (schema) that seems likely to be helpful;
(3) Gradually build a representation for the problem;
(4) Build a representation for a matching piece of “knowledge”
(5) Make two “mappings”, the first linking some of the input data with its representation (linking 1 and 3); the second linking the representation of the problem with the “knowledge” representation (linking 3 and 4);
(6) Evaluate the adequacy of the constructions (3 and 4), retrievals (2), and mappings (5), accepting, or rejecting, or modifying portions of these steps; and
(7) cycle back through steps 1 to 6 as often as necessary to achieve a solution, or the understanding that a solution is not possible (Davis 1984 p 306: on pp 366-367 Davis expands this to ten steps, without significantly altering the general strategy).

What Davis adds to Polya’s four stages is the way mathematics is represented (both as mental structures, and as formal academic knowledge), and the way a learner attempts to match a hypothesised method of solution against the details of the problem and its working out. This is not uniquely Davis’s idea. Others, in particular those focussing on mathematics as a method of “modelling” the real world, see such a process in a similar way.

For example, Edward de Bono outlines several forms of problem solving, including one he refers to as “mathematical thinking”, but which applies whenever we encounter a problem in the real-world, and attempt to find a solution to the problem by re-interpreting the problem in terms of formal knowledge (1977).

According to de Bono:

mathematics is a game played with symbols and rules. The rules constitute a special universe in which things happen according to these rules. Anything enters this universe by being translated into a [mathematical] symbol. The symbol is processed according to the rules of the [mathematical] universe, and then [is] translated back (de Bono 1977 p 230).

That is, for de Bono, mathematical thinking is a kind of “mathematical modelling”, similar to Popperian or experimental scientific method:
• start with a real-world problem situation;
• translate this into the formal world of rules and symbols;
• use the rules for manipulating the symbols, until some solution within the formal world is obtained; and
• translate the formal solution back into the real-world, and check that the interpreted solution fits the problem.

Fourthly, not only does Davis outline a theory of learning (= problem solving, regarded as a mixture of hypothesising, information processing, concept creation, language analysis, non-verbal processing, information or cognitive representation retrieval, and so on), he also outlines a method of teaching which fits this theory, namely, his “paradigm teaching strategy” (Chapter 21). This emphasises meanings, non-verbal thinking, diagrams, and personal experiences, including experience of abstract ideas represented both conceptually and concretely. This paradigm teaching strategy is partly based on Piaget’s process of “assimilation”, fitting new understanding alongside existing knowledge, as well as “accommodation”, creatively drawing on existing knowledge and novel stimuli, to build largely new ideas. Because of the attempt to link the new knowledge to existing knowledge, it is essentially constructivist, in the broadest sense, even though Davis was writing before the theory and the term “constructivism” came into widespread use. Equally, while some theorists regard Piaget as a pioneer “constructivist”, Davis’s discussion is essentially post-Piagetian.

Importantly, through his book Davis repeatedly argues that problem solving IS how we learn, for ALL kinds of learning. How does this fit with your own preferred theory of how people learn, or your own understanding of problem solving?

We learn in an attempt to make sense of, or deal with, a novel situation that we have not previously faced before. This requires us to use our existing knowledge, and skills, responding to the stimulus of the problem, in creative ways. We are just as creative in mathematics, science, sport, and other aspects of human activity as we are in art, drama, literature or dance.

Oddly, and perhaps this partly explains why Davis work has fallen into neglect, the word “learning” which is so prominent in the title of the book, does not appear in the Index of the book. To discover Davis’s definition of “learning” it is necessary not only to read the whole book, challenging for many readers, but to also grasp it as a whole, as Davis clearly did. Far fewer readers, and very few classroom teachers of mathematics, have his breadth of knowledge, or his penetrating insights.

Perhaps what he needed most were a good editor, to insist that the large ideas were made more prominent, and argued more cohesively, and a good publisher, able to produce a widely available and widely read, cheap but highly significant paperback. Richard Skemp had one rather simple idea to offer, but was fortunate that Penguin Books gave him the global English-speaking world in which to say it. Davis suffers, by comparison. Yet it is Davis, and W.W. Sawyer, one of Davis’s listed master teachers (Davis p viii), who can really help teachers teach better. Skemp can only help them distinguish between meaningful learning, and instrumental skill and drilled rote.
It will be illuminating to offer some of Davis’s examples, and leave them as challenges. The important point, one that Davis emphasised repeatedly, is that any self-respecting theory of learning ought to be able to explain what goes wrong when students learn. Yet many theories find themselves unable to correctly answer counter-intuitive questions such as these. Similarly a good theory of learning should also explain what a teacher can do that will effectively eliminate such misconceptions, counter-intuitions, and alternative approaches.

What are YOUR personal theories about the nature of mathematics, how to teach mathematics, and the way that students learn and use mathematics? How would your theories explain the “student” and “expert” “mis-conceptions” that arise when these examples are tackled?

**Two Rolling Circles**

A smaller circle rolls around a larger circle. The radius of the larger circle is three times the radius of the smaller circle. When the smaller circle rolls all the way around the larger circle, how many turns does it make? The so-called “expert” answer is three times. This is wrong! (Davis pp. 217-218.)

![](image1)

**Two Pyramids Joining**

This problem first appeared in the Preliminary Scholastic Aptitude Test for 1980. The fact that it was wrongly handled by experts, and hence was wrongly graded by the test-markers, was sufficiently scandalous that it was reported in *Time* magazine.

![](image2)

The problem is this. Take two equilateral solids, where each edge has length L units. One is a pyramid with a square base, and the other has is a tetrahedron (a “pyramid” with a triangular base). Join the two by gluing together two geometrically congruent faces. How many faces does the resulting geometric solid have? (Also how many edges does the resulting geometric solid have? What if we joined two square-based pyramids by gluing together triangular faces?) (Davis pp 219ff.)

**Vocabulary Retrieval**

Which common four-letter English word ends with the sequence of letters ‘ENY’? (Davis p 237).
Alphanumeric Arithmetic Code Computation

In the following addition, each letter of the alphabet represents uniquely, without repetition one single digits. What digit does each letter represent? (Davis pp 238ff.)

\[
\begin{align*}
\text{SEND} \\
+ \text{MORE} \\
\text{MONEY}
\end{align*}
\]

Conclusion?

Having very briefly argued the strength and importance of Davis’s work, let me end by stressing that my concern is not one of mere nostalgia for old ideas. Nor is it simply a matter of historical interest, to keep a kind of genealogical record of who or what begat whichever later theory.

Rather it is a matter of recognising that Davis’s work is still extremely relevant. It should NOT be forgotten. It still needs to be used.

The fact that so little practical and theoretical attention is currently being paid to Davis, apart from the esteem of colleagues, is lamentable.

If we understand what Davis really achieved in this 1984 monograph, we will recognise anew its potential to be re-expressed, and freshly applied to today’s needs — to help students learn mathematics, and, indeed, to LEARN!

Also, in the light of this small case study, we can identify a neglected research methodology, and consider the power of an ‘archaeology of archives’, which involves an almost literal digging into historical layers of research literature. This helps us reconsider, and hence critically analyse, attractive new terminology and approaches in the light of earlier terms, theories, and research processes. New is not always, and not necessarily better or different. But if we ignore our origins we remain blind to fundamental questions about whether or not we are making any kind of progress.

References


Taking Assessment in (Mathematics) Education into the Next Century: Objectives, Portfolios, Tests and Accountability

ABSTRACT: During the 1970s and 1980s a climate-shift in the teaching profession moved away from formal testing of groups towards alternative forms of assessment, informal cumulative descriptions of individual performances, measured not against other students but against process criteria. Batteries of normed tests gathered dust on storeroom shelves. Teachers went on strike at the mention of the word 'test'. Checklists, anecdotal records, interviews, conferencing and portfolios became the new style of evaluation. Yet in the mid-1990s, internationally, a reworked version of the once-outlawed 'behavioural objective' was hailed as a new key to detailed assessment and curriculum construction — the 'learning outcome'. With shrinking funds for educational services, teacher professionalism and accountability are now more important than ever. Can anything be learned from the once-shunned old approaches to evaluation? How can portfolios and learning outcomes be used effectively? How can isolated Rich Assessment Tasks [RATs] within a problem-solving approach to mathematics form a coherent curriculum? What is 'benchmarking' and how is it related to 'learning', defined as a change in behaviour? Can alternative assessment methods be used to contextualise and moderate formal methods of evaluation? Increasingly, the time available for assessment is diminishing, the content of school curriculum is ballooning, the information explosion becomes global as schools shift to embrace the Internet, new developments in silicon technology challenge traditional approaches to calculation, graphing and algebra, and possible brave new worlds threaten as much as beckon. What is the future for educational evaluation in the first century of the next millenia?

Notes: Sketches of Ideas That Could Be Developed

- Importance of cumulative assessment, rather than just isolated topic-tests. It is essential to treat mathematics as a cumulative subject, in which one topic is expected to be meaningfully connected with another topic. In the past, for fear of hurting students by having them undergo difficult end-of-year and term tests that include questions that range across a variety of topics, many teachers have attempted to make tests painless by reassuring students that, for example, the test tomorrow will only be on 'Area', and the test in a month's time will only be on 'Money'. This is thought to be beneficial to students, because they can study for such a topic-test, if they want to do as well as possible, by studying the announced topic. Once the test is over they can also forget that topic. The real challenge arises when, for example, a teacher asks a question about the cost of carpeting a room, combining aspects of both topics—area, and money. Yet, in reality, students should be able to mix and match topics, letting otherwise separate and forgettable topic concepts and skills interact and strengthen and make sense of each other.

- John Sweller (on myths of mathematics learning) notes that the single defining characteristic of competent problem solvers is not that they have well developed
problem solving skills but that they have been exposed to a wide range of problems, and can call on a large repertoire of mathematical tools to deal with any novel task. It can be argued that the old cumulative end-of-year test, when it is not carried out brutally, actually embodies an essential problem solving skill, namely, the ability to identify a particular task-type and apply the appropriate method or collection of methods to handle the particular task. Moreover there are some topics, such as length, perimeter, area, volume, mass and density which benefit from being taught as simultaneously as possible.

• If they are taught separately students will develop inappropriate theories about the way the topics relate, such as believing that if two shapes have the same area they must have the same perimeter, or that if we change the perimeter of a shape in some way we necessarily change the area. (Here, we can exchange words such as perimeter and area for words such as surface area and volume and make the same general cautionary statements).

• If we tell students that they are about to have a test on ‘-ea-’ words, to take a language education example, the students immediately know that they don't have to worry about ‘-ee-’ or ‘-e...e-’ words, or the subtleties of ‘readjust, reality, reed, head’, and 'heart', for example. If the test is going to be about using the 7-times tables in multiplying, the students immediately know they don't have to worry about addition, subtraction, or division, all of which have direct links with the 7-times table, not to mention place-value, decimal and fraction concepts: (3 x 7) + 33, 65 ÷ 7, 42 – 14, 30 x 700, 12 x 0.07, 3/7 + 5/14, and so on.

• Link evaluation with change-in-behaviour;
  definition of 'learning' = post-test - pre-test

• Emphasise relation between teacher-evaluation and self-correction by students: both are more effective when the nature of the task or topic being taught and learned is made as clear as possible.

• Review the constructive role of evaluation as a process of monitoring student learning, measuring effectiveness of curriculum delivery, provide directive and diagnostic feedback for subsequent small-group and individual teaching, and give directions for curriculum modification: plus giving information for child-parent feedback and reporting - recall the old triangle model of teaching, learning and evaluation,

• Emphasise the general principle of evaluating in the same way that you teach.

* Note that student behaviour can be capricious - right one day, wrong the next; evaluation needs to establish whether student behaviour that has been observed is actually persistent, and whether the student is aware of what has been learned.

• Student self-correction is a natural counterpart to teacher-managed assessment and feedback — it is a constructive step towards a student becoming independent of teachers and school.
• distinguish between learning situations (new topic or skill) and practice (review, consolidation, challenge and extension, remediation, linking other hitherto separate but otherwise known things). Possibly mention Piaget's idea of assimilation (re-working an existing room in a house) as opposed to accommodation (building a new room, or using some parts of existing rooms to make a newish room).

• Stress the importance of having a clear purpose for evaluation: what will the results of the evaluation be used for?
  — checking success or otherwise of teaching and delivery of curriculum (feedback for teachers)
  — reporting back to parents about overall progress at the end of a year (summative)
  — identifying students with special needs, or for instructional grouping (program screening and class organisation)
  — reporting to students about their learning progress (summative)
  — measuring learning change (post-test - pre-test), using the results for any of these purposes
  — identifying levels of mastery, with possible need for extension or diagnostic intervention (formative)

• Discuss process analysis methods, such as Reading Miscue Analysis or Newman Mathematics Diagnostic Error Interviews: the goal is to analyse students' performance of skills and automatic knowledge of 'facts', and identify weak spots in processes which need direct instruction, correction, or redirection and guidance to improve checking, proof-reading and spontaneous independent self-correction. Link this with the recent work (e.g. Cath Pearn's conference piece and related articles) in MAV Conference 1997 on Mathematics Intervention, identifying high correlations between young students' need for Reading Recovery and Mathematics Intervention, and similarly for Bob Wright's work in Mathematics Recovery.

• Mention serious high priority long-term goals:
  — independence
  — positive self-concept
  — curiosity and self-motivation
  — knowing how to learn and enjoying learning
  — constructive recreational life-interests

• Tell the story about growing a tree: you can measure the height of the tree every three months, and be absolutely certain about where the tree is really at, or what level the tree has reached: but the tree grows just the same, regardless of being measured, or not. Many trees in forests do quite well without ever being measured in their entire lives! The point, with classroom measurement, is that when you know where the child is at, this should then have certain clear instructional consequences. If it doesn't then you are measuring (summative) for the sake of it, not in order to do something about the results of the measuring.

• As an alternative, consider school photographs. As long as a school takes regular photographs of whole classes and individuals, the school can genuinely claim to have a true and up-to-date picture of the students and their growth. But what, if anything, is done with these pictures? Feed the scrawnier students peanut butter? Make the
plumper weaker students develop physical fitness? It is what you do with the picture, or as a consequence of measuring, that matters.

- Portfolios: Talk about collecting samples of students' work. This results initially, at least, in unorganised, unwieldy heaps of raw data.
  — How can they be analysed?
  — How can you compare the heap of Billie's work-samples from Term 1 with those in Term 3? How can you compare the Dinosaur project with the work on the History of Clocks? (Chalk and cheese?)
  — Is an isolated piece of work representative? Of course it is possible that a piece of work from one particular day may be unrepresentative, because Billie was having an 'off day' that day. But will the work from good days naturally counterbalance this bad-day sample? Is it valuable to know that Billie may be a student who has three bad-days for every one good-day? Is it helpful to know that, when it's a good day Billie can do amazing work, if the reality is that most of the time the level of achievement is comparatively dismal?
  — How can we make constructive connections between a collection of pieces of work and specific learning outcomes?
  — How can we connect pieces of work with a particular curriculum? How many different pieces of work, or different kinds of work samples do we need to collect to be assured that we have adequate representative information to throw some light on the particular subject or curriculum?

- Is it helpful to have a clearly stated Learning Outcome, with a corresponding question or task that a student can do, and then record how the student handled the task? This can allow you to build up a collection of tasks (with their corresponding Outcomes) which indicate the student's overall performance. Such tasks can be presented to students in the form of worksheets, homework projects, short tests or quizzes, or even as exams. With homework tasks you need to be alert to the possibility that students may have obtained considerable help from others, so that the achievement indicated by the project may not accurately reflect what the student has learned or is able to do unaided. With tests and exams you may need to be cautious in the severity with which time-limits are used, and you should be alert to student test-anxiety impairing the student's ability to perform as well as possible.

- Can we devise a 'map of the curriculum', and chart on it (recording dates of arrival) the individual progress of each student, as the student is helped to explore the territory on the map? Is the CSF something like such a map? What use is made of previous years' records, to provide a clear overview of the progress across years of time of individual students? To what extent is the First Steps program a 'map'? Or the earlier 'Profiles' approaches used in several Australian States and also nationally? E.g. First Steps: Spelling: Developmental Continuum, Department of Education of Western Australia, Perth, (1997)


John Gough — Research Studies
• 'Formative' testing or evaluation is used by teachers to form the subsequent teaching that will follow the evaluation.

• 'Summative' evaluation is used to summarise the progress that a student has made through some period of time.

• Clarify the difference between 'criterion-referenced' and 'norm-referenced' evaluation. Compare this with a curriculum structure such as the CSF-Mathematics, or the National Profiles, which was constructed by a team of draft-writers, who prepared drafts of Learning Outcomes or Indicative Behaviours or Nutshell Descriptors; these were subsequently considered by other teams of teachers who made further suggestions, based on their pooled years of teaching experience, about the appropriateness or otherwise of the suggested 'Levels' of 'Bands' for each of these 'outcomes' (and commented on the clarity, and sense of the outcomes). Hence such 'Outcomes' were certainly not 'normed' by being given as formal test items to a representative sample of several thousand students, and then being statistically analysed to link test-performance levels with age or grade levels, or to rank test-question levels of difficulty. Yet the process of establishing a particular Level for a particular Outcome, based on teachers' perceived judgments and professional experience results in a quasi-norm or pseudo-norm. It has no statistical basis but has the same eventual effective, in that it suggests that a particular Outcome can 'normally' be reasonably expected to be mastered by a certain broad age of school student or stage in the school process.

• Criterion-referenced tasks are not in themselves a bad thing. Nor is there any real alternative to stating some kind of criteria as guides for teaching. It is one thing to criticise 'teaching to a test' (an easy slogan to bandy around, and often taken as some kind of irrefutable criticism of testing; yet teaching to a test is not necessarily a bad thing either, especially when we recognise that evaluation should match instruction, or else run the risk of being irrelevant or misleading). It is quite another matter to criticise 'teaching to an outcome'. This is simply teaching. Without a goal for the task, without a clearly stated outcome, any so called teaching lacks direction, or focus. If the teacher tries to work with no clear possible outcomes in mind, then the teacher cannot be made accountable for what is being done, and any learning that the students actually achieve will have occurred more by accident than planning.

• It is easy enough to state a criterion-referenced outcome. But how can we be sure a student shows that the outcome has been successfully achieved? Evaluation is harder than it looks. We might, for example, specify that a child can do … (pick an example from CSF. But what if the child handles it this way? Or that way (say, using a calculator)? Remember the story of the Physics student who was asked to say how he would use a barometer to find the height of a multi-storey building. The student mentioned how bored he was with the obvious answer that involved measuring differences in air pressure at ground level and at the top of the building. He proposed as a solution, using a long piece of string, and measuring the length of string used to lower the barometer from the top of the building to the ground. The student's favourite answer, however, was to go to the caretaker and say, 'If you can tell me the height of this building or show me an architect's plan, I will give you this fine barometer'!
• Even when we develop flexible methods for evaluating criterion-referenced learning outcomes, another difficulty remains. How exhaustive do the outcomes need to be to encompass the particular curriculum. We might, for example, be able to specify Outcome A, and Outcome B, and to have some worksheet tasks, or observation criteria, or test questions which we believe enable us to establish that these outcomes have been learned. But do we also want to specify the connecting outcome that enables a student to recognise, for example, the way Outcome A and Outcome B are related (for example, linking plane area with surface area of solid objects, or connecting area concepts with volume concepts)? Then, if we do have this extra Outcome A + B, do we also want to connect it with other connecting outcomes, such as Outcome C + D, and so on? How many outcomes are enough? Maybe use reference: Mousley, Clements, Ellerton in Leder Assessment and Learning in Mathematics, ACER, 1992 pp 107-144: Page 135 says that using criterion-referenced tests developed from predetermined behavioural objectives is simplistic and inadequate and fails to provide a clear cut indicator of children's understanding...

• It is commonly said that testing a student and giving the student a number or a letter grade achieves nothing. While this is superficially true, it should be stressed that it may take only a tiny amount of interpretation of such a number or grade to obtain important information. For example, suppose a student in Grade 3 completes the Schleiger Diagnostic Mathematical Tasks (1993) for Grade 3 (the DMT3) in February, or near the start of a school year, and obtains an overall percentage score of, say, 95% (or even something as low as 75%—remember that we can only test with limited measuring accuracy). This result is far more than just a number. It means that the student has in effect completed all the learning that would usually be expected to be covered during Grade 3. Clearly such a student needs new challenges, and might usefully be asked to work through the DMT4 (and if that's OK, try the DMT5, and so on) before deciding just what level of mathematics curriculum would be most appropriate.

• Some schools declare that they have no need for more formalised approaches to educational evaluation because they are using a 'whole language approach', or an 'integrated curriculum', or some other innovative model for teaching. However this may not actually be a reasonable attitude. Unless the 'whole language approach' (or similar scheme) provides an adequate outline of curriculum content and methodology, including detailed guidelines for teaching, monitoring learning, and providing feedback to students and effective diagnostic intervention, the scheme is likely to be wishy-washy, or worse. What, after all, do you teach in, Say, Grade 4? What do you do with a child who, for example, can read many words at sight but has no real comprehension of what is being read? Educational evaluation, where it is effectively linked with practical curriculum planning, is essential to ensure that students are helped to learn as efficiently and constructively (and emotionally positively) as possible. Anything less is a dereliction of professional responsibility on the part of the students' teacher!

Even the most organic and whole-process-oriented 'whole language' approach relies implicitly on learning outcomes of quite specific kinds. These can include such as outcomes as 'can read chapter books with ability to retell or show comprehension', 'can write haiku which are soundly formed meaningful statements using the correct syllable pattern', or 'can spell all of the 100 Most Frequently Used Written Words'. Ditto for CSF outcomes … find some.
• Emphasize the general idea of testing the way you teach, or making assessment methods correspond to the methods of instruction and learning. For example, if a subject includes a lot of laboratory work then make sure that any evaluation also includes laboratory work, perhaps even a laboratory exam. Similarly, if students are expected to work together in cooperative groups, or to perform collaborative tasks as they are learning, then the same teams of students should be called on to work together collaboratively to prepare some form of collaborative assessment of their team-work.

• 'brainstorming' as a collective pooling of background knowledge on a topic, used formatively to identify remaining gaps in knowledge (the teacher is likely to be the one able to identify a 'gap' — students who do not know something are unlikely to know that they don't know), to prompt questions about relationships between terms and concepts identified during the brainstorm, and to be used to attempt to develop concept maps and flow charts and other methods of organising the initially randomly generated brainstormed information into more rationally organised forms, for further investigation. A non-judgmental think-tank approach (in which wild ideas and combinations can be floated with a group, without immediately declaring the idea invalid or irrelevant—how might it be relevant? do Bono's many thinking strategies are extremely useful for this kind of work) can be used, in conjunction with brainstorming, as a way of generating possible solutions to problems, relying on the random combinations and sparks of inspiration that can occur when individuals share their thinking. Obviously brainstorming cannot be used effectively in any summative sense, although some teachers have been known to present the result of a brainstorming session as a resource chart for subsequent tasks such as creative writing.
Spatial thinking, 'space' and 'geometry'

Abstract
Spatial thinking is a special aspect of mathematics which is often neglected or not well understood. The recent move to consider theories of 'multiple intelligence' requires a fresh look at traditional ideas of geometry and not so traditional aspects of mathematics content and thinking. Although Piaget and Inhelder attempted a major study of this topic, and their research has been influential, there is need for cautious and constructive criticism, especially when mathematics curricula and teaching approaches are being widely reviewed.

Introduction
Mathematics is about number and measurement, right? Wrongish. It's about these, and more, about things behind number and measurement. It's about a way of looking at the world and reasoning. Yes, mathematics is about 1, 2, 3, ..., and +, -, %, and \(x^2 + x - 2 = 0\), but it's also about 'triangles', 'parallel', 'similar', 'congruent', ..., and about 'if X is true then Y cannot be true because ...'. Large, intricate, and complicated. Simple, complex, exciting. Pretty. Challenging.

Pretty challenging? How many mathematically different ways can you take four squares, all the same size, and fit them together so that any two squares side by side share a common whole edge, and no square is left unconnected to some other square, and where two squares are not said to be joined if they meet only at a common corner?

Here is the answer, using only three squares at a time.

Figure 1.1: Fitting three squares together at a time joined by whole edges.

And here are several ways that three squares at a time are not allowed to be 'joined'. Can you see why each breaks one of the 'joining' rules?

Figure 1.2: Incorrect ways of fitting three squares together.

Making as many possible different shapes with four squares at a time is a simple enough question perhaps. But consider the detail that is taken for granted: 'shape, square, size, touch, join, share, edge, corner, combinations', and so on. The question 'How many?' refers to mathematics as number. The materials involved are squares, the 'spatial' or geometric aspect of mathematics. The task requires manipulation of elements to create different shapes, a different kind of mathematical work altogether.

Try this: fold a piece of paper three times, then use a hole-punch (or a sharp object) to make a hole through the folded sections: draw a diagram of what the paper, now holed, will look like when it is unfolded. Now unfold it and consider your predictions beside the reality. Think about what mathematical ideas are built into this task.
If it wasn't obvious before, it should be starting to come clear that mathematics is a web or tapestry of concepts and skills, woven from many different threads, knotted and connected in many different ways.

What is 'spatial thinking'?

The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The physical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be 'voluntarily' reproduced and combined ... The above-mentioned elements are, in any case, of visual and some muscular type. Conventional words or other signs have to be sought for laboriously only in a secondary stage ... when words intervene at all, they are, in my case, purely auditive, ...


When spatial thinking occurs, a person considers a mathematical task or question posed in a 1- or 2- or 3-dimensional setting, and forms a mental image of the object or works directly with the object, in order to move towards some solution of the task. Such thinking seems to be virtually wordless, a way of thinking with shapes and images, rather than a linking of word-like ideas. We can say that the solution to the task is achieved by 'insight', a potent word —'in-sight'—seeing inwardly.

Notice that the noun 'space' is turned into the adjective 'spatial', the letter 'c' changing into a 't'. What do we mean by 'space' when we speak of 'spatial thinking'? Despite immediate thoughts of 'Outer Space', black holes, aliens, rockets, stars, galaxies, planets and the solar system, what we are really talking about are those aspects of mathematics which deal with points, lines, regions, angles, rotations, reflections, symmetry, ... all those mathematical ideas which can most effectively be represented by diagrams and models.

Mathematical tasks which involve only one dimension are dealing with questions about single lines, about finding a path from one point to another, about locating a position in a loop or circumference of a circle. The one-dimensional nature of such tasks may not always be obvious. Moving a counter along a *Snakes and Ladders* board, for example, is essentially a one-dimensional activity. Why? The two-dimensional layout of the board is equivalent to a number-line of squares which are numbered (perhaps from 1 to 100). Similarly, counting the hours around an analog clock from one hour to another, or counting minutes in lots of 5, is essentially one-dimensional as the numbers around a clock face are equivalent to a special number-line that loops around at its end to join up with its starting position, like running laps around a race track —twelve on a clock is also a zero!

Two-dimensional tasks involve questions about areas, regions, insides and outsides of a surface, fences around a paddock, flat objects such as kites and chess boards, lines intersecting each other, lines touching curves, and so on. Usually we ignore the fact that a chess board, made of wood or cardboard or even a thin sheet of paper, actually has 'depth' or 'height' as well as 'length' and 'width', just as we ignore the 'volume' of wrapping paper or carpet when we consider questions about the area involved in covering a floor or wrapping a parcel. Notice, though, that we buy house paint by the litre, but do so on a basis of estimated coverage of square metres for the volume-contents of the tin.

Three-dimensional activities deal with the standard ideas of 'length', 'width' and 'height' that we associate with the concept of 'volume' or so called 'solid' objects such as cubes, boxes, cylinders, spheres and cones, which have direct two-dimensional counterparts such as squares, rectangles, circles and triangles.
Working in the former Soviet Union in the 1950s and 60s, the Soviet researcher Vadim Krutetskii (1976) argued that there are three different kinds of mathematical thinking: 'analytic' (which relies on words and chains of logical reasoning), 'geometric' or 'spatial' (which uses images), and 'harmonic' which is a mixture of the other two kinds (p. xiv). It is easy to experience these ways of thinking.

Consider this task, and imagine how you might find a solution:

Three friends visit a library on different days. Alex visits every 3 days, Benny visits every 4 days, and Con visits every 5 days. The last time they were all at the library together was a Tuesday. How long will it be until they all meet there next? What day of the week will it be? (Krutetskii p. 14).

A spatial thinker might use a calendar or number line to work this out, counting successive whole numbers as days in 'bundles' of 3, 4 and 5. An analytic thinker might use the verbal-symbolic abstract concept of 'lowest common multiple'. A mixed or harmonic thinker might combine aspects of both the other approaches, mentally 'skip counting' successive multiples of 3, possibly visualising an imagined number line, and checking which are also multiples of 4 and 5.

While spatial thinking is clearly a natural way of handling a wide variety of mathematical questions, it is not the only way of dealing with concepts about 'space'. The standard school mathematics topic 'Geometry' is often treated in a largely 'analytic' way, using word definitions, sequences of instructions for drawing and construction activities, and rules for logical reasoning.

Albert Einstein described himself very definitely as a spatial thinker. Interestingly, because he was more a physicist than a mathematician, once he had finished his thinking with visual images and signs he sometimes had to struggle to find the right algebraic formulae or mathematical forms to express his spatial insight, partly because he was not widely read in the modern mathematics of his time.

Consider also the international reporting of gender differences in spatial thinking, where males tend to be better than females. How do you rate? Here is a typical spatial thinking task. Imagine you are driving to some place you have never visited before. You consult your handy street directory or road map to check how to get there. Then as you are driving, turning right and left around totally unfamiliar streets, with the street directory on the passenger seat beside you, do you stop, sometimes, to decide which direction to turn next, and find that it helps your thinking if you actually turn the street directory so that the road-lines on the page are going in the direction you are actually facing? Talk with your friends about this task. Although both male and female drivers are equally capable of making a wrong turn, or getting lost during such a task, typically many male drivers will 'move' the street directory in their head, not on the passenger seat, while many female drivers move the map on the car seat in order to see literally which direction to turn.

Isn't 'Space' the same as 'Geometry'?  

When we were at school the mathematics curriculum included a topic called 'Geometry' where we learned about special objects, such as squares, rectangles, parallelograms, rhombuses, triangles, circles, cubes, prisms, and so on. We also learned that, for example, there are 360 degrees in a full turn, and 90 degrees in a right angle, and angles can be acute, obtuse and reflex, and triangles can be equilateral, isosceles and scalene, and so on. We might have learned about Pythagoras' Theorem, and learned how to prove geometric properties, such as that the external angle of a triangle is equal in size to the sum of the two opposite internal angles, or properties of parallel lines and an intersecting transversal. We might have gone as far as studying similarity of triangles, and memorised the special triangle ratios of sides which we refer to as cosine, sine and tangent, the central functions of Trigonometry.
All of these things are part of a 'Geometry' curriculum, but they are also part of a larger topic which can be conveniently referred to as 'Space'. Moreover, most of this Geometry curriculum was taught in an analytic thinking style, emphasising definitions, rules, proofs and formulae. Little attention was given to developing skill with spatial thinking, or even encouraging students to use diagrams except as a first step to establish the facts of a textbook question. In fact often teachers discouraged students from relying too much on a diagram.

This means that many of the ideas discussed here will be familiar, but they now need to be placed in a larger framework. Since you were at school there may have been changes in the more traditional kinds of geometry curriculum. New topics have been introduced, partly for their own sake, partly as intriguing ways of interesting students and trying to motivate aspects of the traditional curriculum. Tessellation (or 'tiling' activities, such as fitting octagonal and square tiles together to cover a bathroom floor — with some tile-cutting to fit against the floor edges) and Escher-type diagrams have become a popular way to motivate standard concepts of 'area'. (You may like to investigate the art and mathematical applications of Maurits Escher, the Dutch artist. Books and jig-saws of his work are readily available.) Questions about reflection symmetry and rotational symmetry have also been used to motivate ideas of angle and pattern.

**Getting started**

Let's begin with a simple task. Which of the following shapes in figure 1.3 are triangles?

![Figure 1.3: Which of these shapes are 'triangles'?](image)

Well, shape A has curved 'corners', and B is made of broken lines, and C is completely filled in, and D is partly filled in, and E is a strange diagram representing a three-dimensional piece of bent metal which was originally an elongated cylinder, and F is a combination of filled in regions including two trapezoidal shapes.

In fact this is a trick question, or at least a tricky question, because mathematically speaking, none of them are triangles! If you look closely you will see that E is actually meant to be a picture of a 'triangle', meaning, the musical instrument called a 'triangle'. But you would be right to say that all of them are 'triangular', because they all have some features which belong to the concept of 'triangle' or otherwise resemble what mathematicians call 'triangle'.

Why aren't they triangles? As you have probably guessed, it all depends what you mean by 'triangle', and this issue goes to the heart of what is being learned when we study Space or Geometry — we explore definitions and the consequences of and connections between definitions.

How do you define 'triangle'? There are several different ways, but mathematically each definition specifies the same group of two-dimensional objects. Here is one definition:

'A triangle is a two-dimensional closed figure or polygon, formed by three straight line segments, where each pair of line segments intersect at one point'.

Here is another: 'A triangle is the set of points in a plane which is obtained by starting at one point, moving a finite distance in a straight line, turning through any angle which is not a multiple of 180 degrees, moving another finite distance in a straight line, and then returning along a straight line to the first point'.
Here is another: 'A triangle is the set of points formed by joining any three distinct points in a plane by straight line segments'.

Here is another: 'A triangle is obtained when we take any straight line segment and create two more line segments by joining the two end-points of the first line segment with any other point in the plane as long as that point does not lie on the straight line formed by extending the first line segment.'

Can you think of other ways of defining 'triangle'?

Notice that the lines or line segments (we might choose to use precise terms, or settle for everyday equivalents and approximations) which form a triangle must be straight (no curves) and complete (no gaps). And the triangle is the 'fence', not the 'paddock' inside the fence, just as a circle is the 'circumference' not the 'disk' enclosed by the outer circular edge. So, technically, a filled-in triangular region is not itself a triangle although it has a triangle as its outer edge or boundary.

Yes, we are splitting hairs. But this is part of the way we need to think if we are to make progress in mathematics. We need to be precise and exact and concise. But we also need to see the general idea behind the technical detail, we need to understand the generic spatial idea of 'triangular' as well as the ruthlessly specific analytic definition of 'triangle'. Moreover, we should realise that many mathematical terms also have related non-mathematical meanings, as in the musical instrument called a 'triangle'.

We can even find that a specialised mathematical term can have different mathematical meanings. The number 4 is, for example, a 'square' – that is, it is a 'square number'. Indeed it can be helpful to demonstrate the nature of 'squaring' numbers, of identical-twin multiplication factors, by using a square-shaped diagram of dots for unit whole numbers. Similarly Pascal's Triangle is not itself a triangle, nor did Pascal actually invent it, although Pascal significantly contributed to its theory and applications, and its construction and numerical relationships can best be displayed in a triangular-shaped chart.

Also, whenever we attempt to teach a new concept we must simultaneously discuss examples of that concept along with examples which do not belong with that concept. Only by investigating those defining features which enable us to distinguish a 'triangle' for example, from triangle-like and non-triangular objects can we really find what the concept of 'triangle' means. Figure 1.4 contains some more almost-triangles and not-triangles.

Figure 1.4: Some shapes which are 'near-miss' triangles.

We make it harder for learners when we set up artificial separations between concepts, ostensibly because we want to avoid confusing the students. For example, whenever we attempt work on 'area', we should also include some work on 'perimeter' (and vice versa), and possibly some work on 'volume' and 'length'. This makes it necessary for students to identify similarities and differences between these concepts. 'The conjecture that equal perimeters enclose equal areas is a strong one. If we are to generate a realistic mathematical attitude, we must allow the children to develop critical powers' (Association of Teachers of Mathematics 1967, p. 315).

Biologists encounter this conceptual task as soon as they attempt to move beyond the common terms for different kinds of animals, for example, and attempt to specify the essential differences, and similarities between such animals as frogs and toads, butterflies and moths, crocodiles and alligators, dolphins and porpoises and whales, and so on.
In mathematics we encounter the need to define clearly, or as clearly as the level of children's understanding will allow, as soon as we move beyond everyday language involved in counting, talking about location of objects, and describing different features of objects. In what ways is an 'oblong' different from a 'rectangle'? Is a 'square' a 'rectangle'? When is a 'diamond' a 'square', and when is it a 'rhombus' and when is it a 'lozenge'? Sometimes the answers to these questions seem hair-splittingly trivial. But eventually, as happens in all matters of definition and attempts to share commonly understood meanings, it all depends on just what you mean, and you can't progress without being as precise as you need to be for the present task.

The problem with diagrams, concepts and examples

Every time we draw a diagram, we run a risk that students who look at the diagram may focus on features which we do not intend to be significant. Let's stick a bit longer with the example of 'triangle'. The standard school treatment of triangles tends to emphasise certain kinds of 'off-the-peg' or 'ready-made' or 'standard' triangles: equilateral, and right-angled, and usually shown in standardised ways, sitting on their flat bottom edges, as in figure 1.6.

Figure 1.6: 'Standard' triangles.

Understandably school children who have only ever seen these clichéd kinds of triangles may be unsure if the following examples in figure 1.7 are triangles, also.

Figure 1.7: Some non–'standard' triangles.

We need to make sure that school students see many different kinds of triangles, in many different orientations, and not just the standard 'posting box' or 'attribute block' kinds of triangles. Figure 1.8 has some slightly 'wilder' examples.

Figure 1.8: Extreme cases of triangles.

These are also triangles, although you may need to make some allowance for the limitations of computer-based graphics. In other words, the intention to show a straight line may have to be accepted, even though the limitations of computer graphics may result in a stair-case collection of dots and dashes. The specific diagrams or objects represent an idea. Students need to form an abstract concept based on specific examples, and counter-examples of not-the-concept.

Richard Skemp (1971) discusses this in The Psychology of Learning Mathematics (chapter 2). By looking at many examples of a concept we are able to form an idea of, for example, 'chair', and we can recognise 'chairness' in different objects, including the one-legged, five-footed, wheel-toed, stoolish thing I am currently sitting in, although we may draw the line at the human-sized open-fronted basket that hangs from a chain on the
veranda of the next-door house — 'chairness' can only be stretched so far, and that is a basket-trapeze, not a genuine 'chair'. Similarly by seeing many examples which our parents assure us are 'red', and many other counter-examples of things which we are told are not red, we develop the abstract notion of 'red', and later, having learned to identify many different words of a similar kind we form the yet more highly abstracted concept of 'color', and perhaps later still develop the color-related concept of 'saturation', and the shade-related concept of 'tone'.

This is a crucial aspect of all learning. We investigate specific examples, and counter-examples, and generalise and abstract from the specific to the idea represented in different ways by different examples. We recognise that a poodle, doberman, spaniel, terrier, collie, whippet, chihuahua, pug, pekinese, dalmatian or an alsatian is a 'dog'. And a 'dog' is not a 'cat'. But dogs and cats are — take your pick — quadrupeds, carnivores, pets, mammals, vertebrates, animals, organisms, and so on.

To identify one kind of dog from another, or to identify one kind of animal from another, we learn to recognise distinctive features (tail, coat, size, spots, ears, etc.). The infant who sees a cow for the first time and spontaneously declares 'Puppy!' is on the right track, but still needs to clarify some of the distinctive features. The three year-old who is given his first toy 'stove', looks at it, places it on the floor, and makes a 'Brrrmm! brrrmm!' noise as he moves the stove back and forth on the floor is making a serious conceptual error. Apart from anything else, the stove has no wheels! (And is a 'dingo', a 'wolf' or a 'jackal' a 'dog'? How 'doggish' is a fox? Is a 'lion' or 'lynx' a 'cat'? a 'genet'?)

Frank Smith describes the role of 'distinctive features' in perception and learning, and the way children develop the ability to attend to different features for different tasks (see Smith 1975, pp. 15–16, and many other books by Frank Smith, a great teacher of psycholinguistic theories of reading and general learning theory).

Sometime orientation is not a distinctive feature, sometimes it is. Which of the following shapes in figure 1.9 is a 'cat' and which is a 'b'?

**Figure 1.9: When does orientation matter for 'cat' or 'b'?**

![Figure 1.9](image)

We need to do the same with geometric objects and concepts about space. Identify distinctive features, become familiar with different tasks, form abstracted concepts, and concepts about concepts, concepts about concepts, and so on, and learn the relations between examples and concepts.

Sometimes the distinguishing features are very subtle, or non-existent and we must interpret from the context. When, for example, is a 'b'-like character a '6' or '9' or 'e'? And does an electronic calculator make such a distinction? What about 's', 'S', '5', '2', 'z' and 'Z', or '3' and 'E', and what about differences between printed text, computer and calculator fonts, handwritten characters, upper-case and lower-case, and so on?

Chuan-Seng Lee and Georgina Herbert (1993), in 'Geometric Diagrams and Geometer's Sketchpad in Primary School Mathematics' raise issues about 'attributes' of diagrams. In particular, geometric objects in Geometer's Sketchpad always have a specific attributes such as the distance from one point to another, or a specific length for any line segment, or a specific angle between any two line segments? But consider the way mathematics teachers draw a diagram of, say, a rectangle, and say it is meant to represent any rectangle? Sometimes this idea of generality is an important feature of geometric diagrams: they are not meant to represent specific lengths or...
specific angles — instead they are meant to represent a general case. Clearly this is one major limitation of Geometer's Sketchpad and other software packages. All cases drawn using Geometer's Sketchpad are specific!

Sometimes a rough sketch is more than enough to identify the crucial features we are referring to. Consider the way many adults rely on a watch which has hands but has no numbers on the dial. Clearly, a visual idea carries a lot of information, not all of which is necessarily part of the message intended to be conveyed at any particular time.

**Investigating 'Space' in three dimensions**

The activities you have been attempting with cardboard triangles can also lead to simple three-dimensional work. Notice that now, if a diagram is difficult to interpret, you need to create a 'solid' object, not just a cardboard cut-out, and manipulate that. Indeed, learning to cope with two-dimensional diagrams of three-dimensional objects can be a major hurdle, comparable to the challenge of learning to read a map as a representation of a real piece of landscape.

Figure 1.10 is a diagram of an object made from geometrically 'congruent' or identical cube-blocks fitted together.

Figure 1.10: A three dimensional object made from identical cubes.

How well can you interpret such a diagram? Assume there are no hidden holes, no extra blocks at the back of the object. How many cubes make this shape? Can you follow this diagram as a plan for building, and use cubes to create the object represented by this diagram? Could you draw a diagram to represent what we obtain if we remove the cube whose front face is labelled B? Or the result of removing the cube whose upper face is labelled C? Or the result of placing another cube behind the B-cube and below and in front of the C-cube?

The diagram is based on the principle that a vertical cube-edge is shown 'vertically' on the page. But horizontal edges in the two major directions being used are shown on the page as line-segments drawn at an angle of 30 degrees (approximately, in this drawing) to the horizontal. The special feature of this way of drawing is that cube-edges appear equally long in the three major directions that they are shown. As long as we only measure lines in the diagram in the three major directions, which are at right angles to each other, or 'mutually perpendicular', we can use the same units of measurement. Such diagrams are called 'isometric', meaning 'measuring equally' (like the term 'isobars' in Weather charts, showing lines of points where air pressure is barometrically equal).

Working with isometric diagrams may take a little practice. In fact this is often the case for almost all kinds of two-dimensional representations of three-dimensional objects. Even photographs of everyday objects, something we take for granted, are not necessarily immediately 'readable'. Infants may need help in learning to interpret photos and recognize a photographic image or realistic drawing of a familiar object as actually
representing that object. Children from some non-Western cultures, possibly less used to photos and drawings, may need careful instruction in school before photos and diagrams become easily 'readable'.

There are other ways of representing three-dimensional objects using two-dimensional diagrams. The best known is the standard 'house plan' or 'building plan' that uses a so called 'birds-eye view', which is like looking down on the building from a height, with roof and ceilings transparent or invisible, and 'side-views' through transparent outside walls.

Notice that a 'map' of a piece of country is essentially a bird's-eye view, with considerable symbolic simplification. The simplification that results from using visual symbols is obvious as soon as we compare an aerial photo or satellite photo of the same piece of countryside with a map or street directory—an interesting activity! But such a simple representation runs into difficulty if the piece of country is sufficiently large for the earth's curvature to complicate our attempt to represent what is actually part of the curved spheroidal surface of the earth on a flat two-dimensional piece of paper—another very interesting activity!

'Spatial' thinking clearly takes us beyond ordinary tasks of the traditional 'Geometry' curriculum? Several of these three-dimensional tasks using objects made from cubes have been loosely adapted from the excellent DIME materials developed by Geoff Giles of Stirling University.

**Are there 'stages' of development in learning about Geometry and thinking spatially?**

The famous Swiss experimental psychologist and education theorist Jean Piaget devised many ingenious experiments and used these to develop extensive theories about the way people learn about 'space' in the world around them. His major study with Bärbel Inhelder *The Child's Conception of Space* (1948) argued that infants and children progress in geometric knowledge from topological concepts, through projective geometry and eventually reach Euclidean concepts only with the advent of formal school instruction—a surprising reversal of the actual historical development of theories of geometry in mathematics.

But this says more about Piaget's personal philosophical tendency to look for surprising evidence of abstract modern mathematics in children's thinking than it does about either the history of geometry or what children really can or cannot do. Despite this, Piaget has been very influential. (Generally I subsume Inhelder into the use of the name 'Piaget' in this discussion, not to belittle her work, but in recognition of Piaget's pioneering significance.)

Without going into too much detail we will consider briefly one of Piaget's more intriguing and appealing spatial experiments: the classic 'Three Mountains' task, which Piaget describes as 'co-ordination of perspectives' (1948, pp. 210–246). The apparatus consists of a physical table-top model of three mountains which look a bit like the sketch in figure 1.11.

Figure 1.11: Jean Piaget's 'Three Mountains' Task.

This should be easy for adults to understand visually. And obviously for the young Swiss children Piaget interviewed and studied, such Alpish mountains were certainly part of their everyday experience. (But consider
how Dorothy on the prairie plains of Kansas might respond to Piaget's questions!) Each mountain has particular identifiable features such as height and color, and a snow cap on the highest, a hill-top cross on the second highest, and a red house on the top of the lowest of the mountains, not shown in this sketch.

The task involves the child identifying a particular pictorial representation of the three mountains as seen from a specified position. To do this the child chooses from a collection of realistic pictures of this model as drawn from several different points of view. (Experimenters nowadays would use close-up scale-model photographs instead of Piaget's drawings.) The child is helped to do this by the experimenter using a toy doll who is supposed to be moving like a real person around the model of the mountains as though the mountains and the doll were real.

What will the doll see when it stands here—at A, B, C, or D, and so on? Piaget had several different ways of asking these kinds of questions.

He interviewed 100 children, ranging in age from 4 years to 12 years old. As a result he described several major Stages in development, each with important sub-Stages—all part of a much larger general theory of cognitive development through childhood—the classic Pre-Operational, Concrete Operations, Formal Operations theory of Piaget.

In short, the youngest, or least developed children who could understand or seem to respond sensibly to Piaget's questions were unable to identify the point-of-view that another observer would have: 'the child distinguishes hardly or not at all between his own viewpoint and that of other observers (represented by the doll in different positions)' (Piaget & Inhelder 1948, p. 212). As far as such a child is concerned, when attempting to imagine another person's point of view, the child believes that anyone else will see only what the child sees. The child cannot see beyond his or her own point of view. The child is locked into 'egocentrism'.

Very interesting. Such children would be baffled by instructions from pre-school teachers and school teachers about performing certain spatial tasks that require an imaginative response to another's viewpoint. Cooperative work in playing with building materials would be extremely difficult.

It takes a brave researcher with an equally intriguing experimental set-up to challenge such impressive research. Martin Hughes, the author of Children and Number (1986), developed a simple counterpart to Piaget and Inhelder's 'Three Mountains', described in Margaret Donaldson's classic Children's Minds (1978, pp. 19–31). Hughes' model resembled a cut-away house, with a policeman doll and a boy doll which looks like this in the bird's-eye view of figure 1.12.

Figure 1.12: Martin Hughes' 'Policeman and Boy' Task.
The boy doll can be placed at positions A, B, C or D. The child is helped to understand the equipment, and questions are asked such as, 'If the policeman stands here [as shown] and the boy is here [e.g. A], can the policeman see the boy?', and 'If the policeman is here [actually placed at B, for example], place the boy so the policeman can't see him'. Very few mistakes occurred, and children were helped to overcome any mistakes. This led to the real test, where two policemen were used, placed in different locations, and the child had to try to hide the boy doll.

Where Piaget found that children up to the ages of 8 and 9 were unable to answer 'Three Mountains' questions correctly, unable to 'de-centre' or overcome 'the egocentric illusion' (Piaget's words, translated, quoted by Donaldson, p. 20), Hughes found that children aged between three-and-a-half and five years could answer his 'Policemen and Boy' questions with an overall accuracy of 90 per cent. And four-year-olds could handle even harder questions with the same success rate. Who is right?

Piaget's work has been replicated by others. Hughes' work stands up to experimental scrutiny. What is at stake is the interpretation offered by both researchers, and critical comparison of the two experiments. According to Donaldson the key difference is that some of Piaget's younger children actually did not understand the task, although this seems not to have been obvious to Piaget. Hughes was able to use a simplified version of the 'Three Mountains' task with pre-school children and, given careful help to make sure they understood what they had to do, most of them succeeded.

But more importantly, Donaldson points out that even three-year-old children know what is involved in 'hiding' from some one. Though of course few children are used to really hiding from policemen, 'hiding' is a widely played young child's activity. That is, the Policeman task 'makes human sense' (emphasis in Donaldson's original, p. 24) where Piaget's task is clearly harder and also less humanly sensible because the motives and intentions of the imagined players in the task is not obvious.

This discussion of two key research experiments may be enough to whet appetites for further reading or research and theories, or to indicate the caution we need to exercise when faced with apparently compelling experimental evidence that children can or can't do certain things—or that they pass through certain stages at particular ages. There is a difference between being influential and a pioneer, as Piaget unquestionably has been, and being reliably right and helpful in the classroom.

**One more theorist-researcher**
Just as Hughes came to his research in critical response to Piaget's influence, another contributor to developmental theories about geometry attempted to build on and correct Piaget. Dutchman Pierre van Hiele and his wife Dina van Hiele-Geldof worked in the 1950s on the response of school children to instruction in traditional (Euclidean) geometry. This research began with two parallel doctoral studies. Following the early death of his wife, van Hiele continued their joint work, and his research articles and major study *Structure and Insight* (1986) has had considerable influence. The following discussion draws on the Australian-based research of John Pegg.

According to van Hiele, students move through five identifiable Levels of thought or geometric understanding which may be described briefly as follows (adapted from Pegg 1990, pp. 427–428):

**Level 1:** Students identify figures by their shape as a whole. An object (say a trapezium) is what it is because it looks like it, a square and a rectangle are seen to be different. A typical comment from a student at this level is that 'a rectangle is a longer square'.

**Level 2:** Students identify figures by their properties. However, the properties are independent of one another. A typical response might be 'a square has four equal sides and four equal angles'. Squares and rectangles [which share some of the stated properties] are still seen to be different.

**Level 3:** Students still identify figures by their properties, however relationships between properties are observed. A typical response might be 'an isosceles triangle has two equal sides', but if probed about the angles the student will say 'if the sides are equal then the angles opposite them must also be equal'. A square is now seen to belong to the class of shapes called rectangles. Concepts such as parallelism and congruence emerge as principle aspects to be explored and used even though they had been known and talked about at lower levels.

**Level 4:** Students can reason in a formal (deductive) way. They can solve theories [or 'theorems'] without relying on rote learnt steps that need to be followed.

**Level 5:** Students can work within systems based on different axioms and study other [non-Euclidean] geometries which are not based directly on [Euclidean] experience. An example would be projective geometry.

We notice in the examples offered by John Pegg the typical sequence by which students at first distinguish in everyday terms between 'square' and 'rectangle' (and the term 'oblong', which is an everyday synonym for the mathematical term 'rectangle'), and only later accept the mathematician's view that a 'square' is a special case of a 'rectangle', and also that a 'square' is a right-angled example of a 'rhombus'. In fact 'rectangle' and 'rhombus' are also included in the larger category of 'parallelogram' and this is in turn included in the still larger category of 'quadrilateral', itself a category within the general family of 'polygons'.

The successive development of finer and finer distinctions between definitions or categories is often problematic, and 'square' and 'rectangle', initially discrete concepts, later being seen with 'squares' as a subset of the set of 'rectangles', is a classic example. Exactly the same difficulty arises in the successive refinement of zoological concepts. Typically, many students at first find it shocking or at least puzzling to include 'birds' as a subset of the larger category of 'animals', and commonly rebel at the teacher's suggestion that 'humans' are also
'animals'. Van Hiele and Pegg are right in their analysis and description of a theoretical intellectual sequence of levels of understanding – from everyday concepts to formal definitions and abstract deductive skills. But whether this has any relation to psychological developments within an individual or learning stages is another matter.

For example, notice that in Pegg's account of van Hiele's theory Level 5, in particular, assumes that direct experience of geometry is 'Euclidean'. However, whatever the limitations of Piaget's research, it seems clear that infants' and very young children's perceptual world and thinking is based on the non-Euclidean concepts of 'near, far, in, out, touching, not-touching' and so on. That is, so called 'direct experience' may not be inherently Euclidean at all.

Straight lines, angles and so on are human conceptual constructions which provide an abstract basis for certain kinds of human activities. We only need to step into a world of plaited wattles and round-walled round-roofed mud-thatched huts, or the well-known hemispherical Inuit igloos, to realise that 'straight' and 'angle' are also culture-relative, and not necessarily part of direct experience unless you happen to live in a world built of bricks and planks and right angles, dominated by tools and machines and school-based approaches to language and concepts.

The van Hiele Levels are certainly interesting. Pegg and others have used the Levels as structural guides for approaches to developing geometric curricula. For example Pegg suggests that teachers encourage students:

- to concentrate initially on the properties of a rhombus. Not until students are familiar and comfortable with these properties is it suggested that work involving [compass-and-ruler] constructions (such as bisecting a line and drawing perpendiculars) should be commenced. Such an approach allows teachers the chance to let students, who are at Level 2, work at their level of understanding in carrying out and explaining constructions (a topic teachers often cite as difficult to 'teach'). The end result of such an approach is that students can talk about the reasons why the constructions 'work' in terms of the properties of a rhombus. They do not need to rely on remembering a number of 'tricks' that they do not understand and need to memorise.

Pegg 1990 p. 428

This sounds convincing. But so did Piaget's 'Three Mountains' research. Let us now consider what possible flaws there might be in such a view?

To begin with, van Hiele and those who use his ideas, seem to be confusing the idea of 'development' with the experience of schooling. Piaget's theory, with its Stages of Pre-Operational, Concrete Operations and Formal Operations, argued that children cannot be 'taught' how to move from one Stage to another. Rather, if a teacher has any role in helping students move onwards through their cognitive developmental stages, it is only to provide as much rich and suitably structured experience as possible, from which students will be able to make their own discoveries and 'grow' through this experience to a new way of thinking. Pegg, in discussing the reported difficulties with compass-and-ruler constructions, seems to be similarly hesitant about the possibilities of 'teaching' being effective.

But Piaget's ideas, about providing rich experience and challenging materials and activities, distinguish between traditional approaches to school curricula (lesson A, followed by lesson B, and so on, developing concepts and skills in order x, y, z, and so forth) and a kind of uncontrollable mental growth that corresponds with physiological growth (such as the onset of puberty, given a sufficiently nutritious diet). You can't teach people to become taller. You can't teach children to physically mature into adults. You can't teach people to
move from Concrete to Formal Operations. But with a good enough 'diet' or experience, they will get there themselves—according to Piaget and Piagetians.

Whatever we may think of such claims, this is obviously very different from any comparable claim by van Hiele or his followers that you can't teach people to move from, say level A to level B. Different precisely because van Hiele's identified Levels are so clearly tied to different stages in a traditional geometry curriculum. It seems impossible to imagine any way that a student could move from, say, Level 3 (structured geometric vocabulary) to Level 4 (standard Euclidean proofs), or from Level 4 to Level 5 (non-Euclidean geometries) except by the direct intervention and instruction of a teacher wielding a well structured geometry curriculum. Whereas it is possible to imagine a student moving from Piaget's Pre-Operational to Concrete Operational Stages simply through rich experience and natural 'growth'.

As for moving from Concrete to Formal Operations, especially in mathematics where the move is one from number work to algebraic work, and beyond, it is extremely difficult to imagine how this can be done without teachers. But that is yet another criticism of Piaget's theories which need not detain us too long here. The more you look at hard details of school curricula, the more Piaget seems to have less and less immediate relevance or constructive implications for the business of teaching and working with children and their school-based mathematical thinking especially in the transitional stages from arithmetic to algebra. (Further details can be found in the specialist research discussion by Clements and Gough 1978.)

Separate from these remarks, notice also the way Pegg, for example, emphasises that students should focus on restricted geometric topics, such as the rhombus, until these are 'mastered' or sufficiently understood to be able to become the basis of extension to further and other topics. But Pegg himself identifies a key limitation:

… if this idea was pursued in detail then the process would need to be repeated many times (i.e. with many figures) before a satisfactory basis, across a large section of Geometry, was established ... apart from the tedious repetitive nature of the activities, it is not clear that the sum of the repeated procedures would ever give a satisfactory holistic answer for the student.

Pegg 1990 p .430.

Pegg's discussion goes on to consider van Hiele's suggestions for overcoming this limitation. However the overall implication seems to amount to little more than the obvious point that teachers should proceed to teach geometry as well as possible, bearing in mind that students may not always understand at first, and may take time to come to grips with the real implications of the curriculum.

Is it dangerous to over-simplify mathematics instruction?

What if we believed Piaget's argument that some children may not be ready to deal with tasks such as the 'Three Mountains', or other 'conservation'-related activities? Or if we believed that a valuable implication of van Hiele's theoretically proposed Levels of geometric thinking was that we should ensure that students all understood a topic before moving on? It seems we would spend a lot of time not even trying to move forwards, for fear of confusing students, or of presenting cognitive tasks they were incapable of handling, or of attempting to build on concepts and skills that were not yet understood or mastered but had only been encountered and grappled with in rote ways.

Moreover, in the effort to ensure that students always understand and master any particular topic before attempting to move on, we would try to strip each teaching topic down to its simplest possible pieces, each of which would be taught as simply as possible, separately from other ideas which might be too readily confusable with the learning objectives currently being attempted. We would also try as hard as possible to show how
these simplest-possible building bricks related to important activities in the real world—we would emphasise practicality and relevance wherever possible.

But 'understanding' and 'mastery' are slippery educational goals. Often understanding only arises in hindsight. And 'mastery' is limited, relative to the particular task at hand. What I have mastered about 'squares', for example, is seen to be incomplete as soon as I realise that a 'square' is also a 'rectangle', or that a 'square' is part of Pythagoras' Theorem, or that a 'square' is the result of translating a line segment within a plane perpendicularly to the orientation of the line segment, or that a 'square' has four axes of reflectional or line symmetry, and also has rotational symmetry. That is, what is 'mastery' at a particular stage of learning, is only 'partial mastery' within some larger piece of learning. We have never completely 'mastered' or 'understood' some concept, although it may be comforting to think that we have. Mathematics is 'like a jigsaw that never ends. Just as we build up a "real" puzzle by completing a small bit of the border here, a little of the house in the picture there ... as small entities fit into place, yielding a satisfying picture, so, it seems, does our awareness of mathematics develop' (Association of Mathematics Teachers 1967, p. 310).

Moreover the instructional crutch of 'relevance' and real-world usefulness, valuable though it may be sometimes, may actually conceal from students the fundamental underlying ideas. Typically, Economics students who study the Mathematics of Economics learn calculus that is so utterly dedicated to Economics applications that they have no idea at all that they are learning one of the great achievements of mathematics, and are completely incapable of applying the ideas they 'master' within an Economics setting to any other relevant subject. At Primary levels, it may be difficult to argue for relevance of 'symmetry', for example, or real-world applications for learning to read Roman numerals or for distinguishing isosceles from equilateral triangles. However, the sheer intellectual challenge involved in grappling with such issues, and their underlying general non-real-world significance, should be sufficient justification for suggesting that Primary students might enjoy learning about these things, and benefit from that learning.

**Using mathematics games to develop spatial thinking and geometry**

One way of focussing fairly painlessly on geometry and spatial thinking is through certain kinds of board games. Here are some suggestions (adapted from Gough 1994). Keep in mind, though, that some people do not like board games. What is fun for you may not be fun for me, and vice versa. Alternative activities include construction materials and kits such as Lego and Meccano. Similarly there is considerable spatial thinking in following the instructions for building a plastic scale model, or a boat-in-a-bottle, or other construction kits.

**Conclusion**

Spatial thinking is a way of doing mathematics, thinking mathematically, as much as it is a piece of curriculum content which includes aspects of what we traditionally call 'Geometry'. Always remember that part of this mathematical thinking involves problem solving, while another, possibly more important part, involves the forward-looking aspect of problem solving known as problem posing. I have deliberately written this discussion so that it does not work as a teaching guide, step by step, lesson by lesson, topic by topic, to a piece of curriculum. Instead I have tried to present questions which seem immediately intriguing, attempting to show a role model of problem posing, inventing new questions rather than harking back to familiar materials.

This is not meant to be a criticism of familiar questions or standard approaches to this topic. A well constructed textbook treatment of, say, properties of a transversal intersecting a pair of parallel lines, or area and perimeter of irregular polygons, or an investigation of Platonic polygons and their three-dimensional polygonal counterparts, is still a valuable teaching resource. But it is important to try to make sure that such a treatment is used from a problem solving point of view, and, as much as possible, is used as a springboard for asking new questions. Now we have learned this: how can we use it, and what else can we do?
While Spatial thinking is largely non-verbal, it helps to keep in mind theories of language learning (including the psycholinguistic theories about oral language acquisition, learning to read, and learning to write), to give language-based insight to the processes involved in learning non-verbal concepts and skills. The fundamental processes of learning and making meaningful sense of experience seem to be the same whether they are being applied to verbal or non-verbal learning, or to psycho-motor learning, or socio-cultural learning, and so on — including music and art.

In a Primary class of mixed ability children, investigating the theme of 'Furniture', questions arose about the way trees were sawn lengthways and turned into planks of wood. One further question was, what shape is the cross-section of a tree trunk if it is cut across the trunk? And then, what is the cross-section when the cut goes at a slant? (Association of Teachers of Mathematics 1967, p 125). In fact questions about predicting cross-sections occur in Piaget and Inhelder's experimental studies (1948 1956, chapter 9 'Geometrical Sections') and Piaget also investigated children's ability to draw a picture representing the drawing of a water-level in a half-full bottle that is standing upright, lying down, or tilting half-way between horizontal and vertical (chapter 13 'Systems of Reference').

Try these tasks yourself. Then consider the comments that follow, speaking to us from thirty years ago!

Having seen an object cut across is not enough. It is no good asking the child to 'look' and draw what he 'sees'. Until he has met some conventional representations or symbolizations of the kind of thing he is to look at, he has no idea how to select what he should attend to, and no idea how this could be described or represented.

Children have to learn how to look, how to select what to look at, and how to look at it. In this learning process symbols play an essential part; they may be gestures, words, or signs or drawings. The child acquires them by seeing and hearing them used in appropriate contexts, and at any stage the 'vocabulary' of symbols that he knows is growing and developing, increasing his ability to comprehend. It is not just that the extent of his 'vocabulary' determines how much he understands of what is 'said', although that is part of it; nor that his 'vocabulary' determines how much he can communicate of what he understands, although that is another part of it. But the words and signs at his disposal have a more dynamic life; they are the tools he needs for his explorations.

Every teacher knows that this is true in the case of [verbal] language. Words are not solely for talking with. They are part of the process of structuring experience and giving it meaning. The same is true for any other system of symbols, and in particular for the system of conventions that we use to describe shapes: the models we make and the diagrams we draw. Certainly the figures we draw are not merely copies of nature. Squares and rectangles and circles are as much abstractions as numbers are, and we would never arrive at them by simple observation of things around us.

(Association of Teachers of Mathematics 1967, p. 126: emphasis in the original)

This is the challenge of Spatial thinking and Geometry — to provide necessary tools for (mathematical) exploration of the physical world, linked with our culturally-constructed intellectual world.

References


Spatial Thinking and the D.I.P.T. Analysis

[Developed from an earlier version with the same title in Prime Number vol. 6 no. 2 June 1991 pp 3 - 5.]

Spatial thinking occurs when we make a mental picture or model in our head and then use that picture or model to work out an answer to a problem. We may use spatial thinking whenever we drive a car, or park a car (to say nothing about reversing a car!), set a table, choose which saucepan to use, decide the next move in a game of chess, slice the remaining two-thirds of a pie to serve five people, and so on. Of course spatial thinking is not the only kind of thinking. But it is very important, and often neglected in schools.

Here is an example of an everyday task and some different ways of dealing with it. When we are moving furniture, we might bring a large table up to a narrow door. The problem is: how can we get the table through?

There are several ways of answering this. One way would be to physically manipulate the table until we find a way of getting through. This direct trial and error, turning and pushing a real physical object, is a weak kind of spatial thinking. Alternatively we might imagine that, if we tip the table over on its side, and if we then poke two of the legs through first at one side of the door, then we can slip the rest of the table through, giving the table a careful turn so that the rear legs fit through at the end. This time the problem is solved, or a possible solution is offered mentally, without actually carrying out the physical task at all. Such use of our three dimensional imagination is real spatial thinking.

Another alternative would be to measure the three dimensions of the table, to measure the door and adjacent walls, and maybe to do some trigonometry or Pythagoras calculations. Then, from all of this analysis of the situation, construct a possible solution. This is not spatial thinking at all, unless we make scale diagrams to assist our calculations. It is another way of thinking mathematically - essentially it is verbal, "analytic", formula-based, formal mathematical thinking. By contrast, spatial thinking is non-verbal, wholistic, imagistic. In a very literal sense, spatial thinking is essentially a matter of "in-sight".

As this example suggests, there are two different ways of thinking mathematically - "analytically", and "spatially". A third possible way is to combine these two in some way, perhaps doing some of the work analytically, and some spatially. Most people who have learned to think mathematically (which is, in fact, most people), think either analytically, or spatially or both. This description of "analytic", "geometric" (i.e. spatial), and "harmonic" (i.e. mixed analytic and spatial) types of mathematical thinking was developed by the Soviet researcher V. A. Kruteskii (1968, 1976, p 315).

But if we look carefully at most mathematics curricula, we will see that spatial thinking is given very little emphasis. The instructions are given in detailed verbal, analytic prose. The diagrams are explained analytically using labels, and causally linked sentences. Even those areas of curriculum that might be expected to be handled by spatial means are actually dealt with analytically as much as possible. In topics such as area or volume, for example, most curricula will move on to algebraic formulae to handle length by width, and so on. Routines will be introduced to enable a complex area or shape to be broken down or analysed into manageable bits, rather than trying to find a way of dealing with the whole task.
Compare the average page of a mathematics textbook with, for example, a Lego manual which instructs children how to build some particular Lego model. The step-by-step Lego instructions analyse the task down into little manageable bits, from start to finish, brick by brick. But it is all done without words. Each step is a picture of what the model should look like now. Certainly some children will respond to this analytically, carefully identifying which Lego block fits where against which other Lego block, sometimes even counting the little dots or bumps on top of the blocks. But others take all of this in at a glance, and build directly from the diagrams, thinking spatially.

This means that there is a discrepancy between the almost wholly analytic approach adopted by mathematics curricula and textbooks, compared to the way that many people rely on spatial thinking.

A further complicating factor is that a wide range of international research tends to show that on almost any spatial task, males are more able to think spatially than are females. To a large extent this may reflect current cultural differences in upbringing and expectation. It is the boys who tend to be encouraged to climb trees, build cubby houses, play with Lego and Meccano, throw stones, steer billy carts, read maps, saw wood, dig holes, put up tents ... and so on.

We may want to challenge such cultural stereotypes. There are always exceptional cases that do not fit cultural categories. Tom-boys rebel, and some become Olympic target shooters, or engine drivers. Some boys become chefs, and fashion designers and hairdressers. Also there seems to be a trend to counteract stereotyping within schooling and within the community generally. Kind aunts give footballs to their little nieces, and doting uncles give dolls' houses to their nephews. Nonetheless, examine any toyshop, and the current stereotyping that still exists is immediately obvious: dolls, fairy costumes, toy cookware, toy jewellery and pink and pastel things to the left, guns, cars, trucks, fighting heicles and heroes, and red and black things to the right (or vice versa), all gender-categorised, and color-coded on the basis of gender-biased market research.

Do boys play with Barbie's friend Ken? Do girls play with Skeletor or Swamp Thing? We will be waiting a long time before we see serious change in market-driven gender-coding, before we will be able to buy user-cuddly 'Conflict-Resolution Man, With Problem-Solving Suggestions!', as envisaged by Jane Sullivan in her article 'Children and Violence: When Does It Start?' (1996).

It should be clear, then, that the current mathematics curriculum's emphasis on analytic thinking tends to ignores spatial thinking. This is likely to disadvantage the half of the population that is female, as well as the rest of the population that may prefer to handle mathematical thinking spatially.

Here are some more spatial tasks to consider.

1. Imagine an analog clock (i.e. one with hands) showing 12:30.
2. Draw an analog clock showing 12:30.
3. What time will this clock show one and three quarter hours after 12:30?
4. What direction do you need to point so that you are pointing at the sun at noon in June (or in December)? (The answer, in Australia, is not simply "up" - think about it.)

Consider the different kinds of spatial thinking involved in such everyday tasks, and the different ways that people can handle the tasks. Starting with the first question: What does your mental
image of the clock look like? Are there numbers on your mental image of a clock face? What kind of numbers, ordinary Hindu-Arabic, or Roman, or computer-style? What kind of hands, plain, ornate scroll-work, Mickey-Mouse-gloved hands? Then consider the second question: How are the numbers placed on the drawn clock face? If you have used Roman numerals, look at the numeral for "four o'clock" and if possible find a real clock with Roman numerals to compare with your drawing. Is the hour hand correctly placed on the drawn face? How have you answered the third question: Have you drawn a picture of the clockface one and three quarter hours after 12:30? Did you do any arithmetic to find what the subsequent time would be? With the last question: What kind of mental image of the sun, or Australia or the Earth did you make?

If we want to give extra attention to spatial thinking, it is helpful to be able to analyse different aspects of this complex, natural process. In 1977, Ken Clements and Nongnuch Wattanawaha published "The Classification of Spatial Tasks Suitable for the Classroom". This provided four separate variables for analysing spatial thinking: Dimension, Internalization, Presentation and Thought — D.I.P.T.

Their original intention was that the DIPT analysis would allow teachers to identify differences between tasks. However further research showed that different individuals were likely to handle tasks in different ways. And how a person handled a task one time might be quite different from the way it is handled another time. This meant that it was impossible to anticipate completely or exactly the spatial nature of a task before seeing how a particular person would perform the task.

The real value of the DIPT analysis lies in its identification of the particular way that the task is being performed. When diagnostic interviews are carried out, where the individuals perform certain mathematical tasks, showing and explaining as well as they can what it is that they are doing, it becomes possible to identify how the individuals are thinking, analytically and spatially.

Also, by focussing on D, for Dimension, the DIPT analysis stresses the possibility of spatial tasks that use one dimension, or three dimensions, in contrast to the usual predominance of two-dimensional tasks. Similarly, by identifying different ways of making and using images (Internalization), and different ways of presenting the result of the task (Presentation), it is possible to design a range of tasks that will include this variety of spatial performance.

If mathematics curricula are to deal with spatial thinking more effectively, they need to offer the widest possible challenge. Of course, individuals will respond differently to tasks, regardless of the intention of curriculum designers. But this is true for analytic tasks as well as spatial thinking tasks, as research on children's invented informal strategies in arithmetic is currently showing.

To carry out a DIPT analysis, start by deciding just what the task is that will be analysed. Then consider how many spatial dimensions are involved in the task. Does a person need to form a mental image of something in the task? Does anything need to be done with the mental image? How will the result of the task, or the "answer" be presented? What kind of thinking is involved in carrying out the task?

Depending on the answers to these questions, the DIPT analysis rates or scores the answers with a numerical code. Different tasks, and different ways of doing the task will have a different score which indicates these differences.
**D = Dimension:** this is scored:
1 for a one-dimensional or linear task
2 for a two-dimensional task that involves a surface or area
3 for a three-dimensional task that involves a solid object or three-dimensional space.

Some spatial tasks may involve three-dimensional objects but actually involve only two-dimensional thinking; for example, in working out which chess piece to move, the chess piece is a 3-dimensional object, but the move takes place in only two dimensions.

Even the jumping move of a knight is essentially a 2-dimensional move from one square to another: usually the third dimension of depth or height is irrelevant in board games.

Some tasks may involve 2-dimensional objects, but because they must be manipulated in a third dimension the complete task is really 3-dimensional. For example, using a contour map to plan a route, or playing a pentomino game where pieces may be flipped over, are tasks that involve thinking in a third dimension about 3-dimensional objects.

**I = Internalization:** this is scored:
0 when no mental image is needed to obtain a solution or carry out the task.
There maybe a picture or object provided with the task that means no image is needed
1 when a mental image is required
2 when a mental image is required and this image must be mentally, spatially manipulated in some way

**P = Presentation:** this is scored:
0 when no picture or object is required in presenting the result of doing the task.
The result may be a word or number
1 when a picture or object must be selected from several given alternatives.
This is typical of multiple-choice tasks
2 when a picture must be drawn or an object must be constructed. This picture or object corresponds to the final mental image

**T = Thinking:** this is scored:
0 when none of the following are needed, or when the task specifies which of the following skills are to be used
1 when any arithmetic calculation, measurement, logical arguing or other kind of formal reasoning is required but not specified by the task

Generally, once a DIPT analysis has been carried out, the higher the score for any of the four variables, the harder the task is to perform.
This kind of information contributes to the assessment of ability and skill.
How does this work in practice? Consider the four spatial tasks mentioned earlier. Certainly different people may respond differently to these tasks. But discussing a general DIPT analysis for these tasks will help to clarify the DIPT classifications.

1. Imagine an analog clock (i.e. one with hands) showing 12:30.
Here the image to be formed is essentially 2-dimensional. Someone might have imagined a large Swiss cuckoo clock which is built like a solid house. Any clock is actually a 3-dimensional physical object. But the essential nature of an analog clock involves only two dimensions: up and down (one dimension) and across (the second dimension). So here D = 2.
The task requires a mental image to be formed. But nothing has to be done, mentally, with the image. So I = 1.
There is nothing to be presented or selected or drawn or constructed. So P = 0.
Very few people would have to stop and think about imagining a clock. No one needs to do any arithmetic or work out any steps of logical reasoning. So T = 0.

2. Draw an analog clock showing 12:30. Again, D = 2.
Most people will immediately know what 12:30 looks like. Certainly they will form a mental image. But this will not need to be manipulated mentally. So again I = 1.
However, most people will get the hour hand in the wrong position. Those who get it right may have had to mentally correct their initial image by mentally turning the hour hand clockwise (how much?). For these people, I would be 3.
Presentation is different with this task. There is no selection to be done, but a drawing has to be made. So P = 2.
If the question had asked: Which of the following clock-faces correctly shows 12:30? the task would have involved selection and P would have been 1.
Most people do not need to calculate or reason to be able to draw 12:30. So T = 0.
But anyone who consciously worked out where the hour hand points would have scored T = 1.

3. What time does the clock show one and three quarter hours after 12:30?
Some people may respond to the ambiguity of this question by simply calculating and then stating the time. For them, the question is numerical, not spatial, and there would be no Dimension or any other DIPT category to be considered.
Other people may
(a) handle the question spatially but give the answer as a number.
(b) handle it spatially and give the answer by drawing the clock face.
(c) calculate the answer, but show the answer by drawing the clock.
For all of these different possibilities there are different DIPT scores for the way the task is performed:

(a) $D = 2, I = 2, P = 0, T = 0$
(b) $D = 2, I = 2, P = 2, T = 0$
(c) $D = 2, I = 1, P = 0, T = 1$.

4. What direction do you need to point so that you are pointing at the sun at noon in June (or in December)? (The answer, in Australia, is not "up").
Try a DIPT analysis of this task.

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Critique: The Impact of ICT (Information and Communication Technologies) on School Education — A Case Study


Information and Communication Technologies have been a long time coming. Behind the anticipation, and hype, what is the developing reality? What appears to be best practice? What, by contrast, is typical practice? Where are the gaps between inflated rhetoric and sober reality? Critical analysis is a crucial research tool, faced with confusing, sometimes meaningless terminology, and a seriously limited research base. This critique of research and policy becomes even more important as State and national authorities rush to embrace the new waves of user-friendly computer-based learning tools and the communication and resource extravaganzas offered by e-mail, the Internet and web-based information and interactivity.

Introduction: What’s “Critique”?

I chose this topic, a research methodology called “critique”, with a case study, as I was searching for something to present to this Symposium, while mindful of my earlier work in related areas. At the same time I was making extensive critical notes on a new book by Lankshear, Snyder and Green (2000), preparing to review it. (Let me stress that in discussing this book, and other case study materials, I am not being willfully or only critical. Lankshear and his colleagues say much that I commend, as I will show. My work as a critic is constructive, and appreciative, as much as it is analytical, questioning, and only occasionally includes complaint.) I realised, as the pages of notes accumulated, that I was carrying out a form of research — I was “critiquing”. Could I draw on this fresh experience, and present this approach to research to the Symposium? Let’s see.

Critiquing is closely related to earlier methods I have discussed, such as playing the part of devil’s advocate (Gough 1998b), and conceptual testing (Chandler and Gough 1999). Concepts are analysed, arguments are assessed, conclusions and examples are tested for their logical consequences and tried against possible counter-examples. The method of critique is flexible and informal. It is not rule-bound or procedurally prescriptive. It adapts to fit the particular case being considered.

The conclusions that follow an effective critique are corrected errors, clearer understanding, an extended and carefully balanced and examined context, with a cautious, critically constructive re-interpretation of existing research. Beyond that there are suggestions for possible future research, new directions, and re-focussed goals.
As with other, more familiar forms of research, the outcome of critique is “new” knowledge, or existing knowledge seen anew. While critique itself does not usually generate its own fresh research data, it can include the analysis and meta-analysis of existing research data. In its own modest way it advances what we know — in limited ways, assuredly. But nonetheless this is a worthy goal to aspire to, and I believe that the method is worth considering at this Symposium.

**Research Question: What is the impact of ICT (Information and Communication Technologies) on schooling?**

The information technology revolution has been looming for decades. Once it consisted of classes in which a keen teacher, probably studying at university, or recently graduated with brand new computer science training, would hand out data-input cards, and a paper clip, for students to punch out tiny holes, to be read by light meters in a photo-sensitive program-compiler. FORTRAN, probably. Hands-on. For the dedicated hard-core minority. Circa early-1970s.

Then the breakthrough, or not having to breakthrough, when a pencil could be used to mark the data-input cards. These cards, of course, would be delivered to a friendly university-run mainframe computer, and students would get back the results of the programming several weeks later. Hard work! Circa mid-1970s.

A fresh breakthrough occurred with the invention of the micro-computer — we know them as “desk-tops” or “workstations”. Circa late-1970s, early 1980s.

Any school that purchased an Apple IIe, or an IBM 286 (or Microbee, BBC, Commodore 64, or Tandy RadioShack WhatEver, etc.) could enter the “personal” computer age. Five-and-a-quarter-inch floppy disks, and a monochrome screen, and dot-matrix printer … and students struggling to learn how to wordprocess, and create and interrogate a database, and use educational skill-and-drill and game-type practice software, and maybe do a little BASIC programming, or LOGO, typed in capitals, with numbered lines of commands. This was supported by pencil-and-paper preparation, which was then laboriously retyped at the computer keyboard, and by chalk-and-talk lessons on Computer Awareness, or Computer Literacy, as a new school “subject”. Each student would be lucky to get an average of 1 hour per month actually working on a computer.

The next wave of the revolution consisted of schools beginning to develop laboratories of micro-computers, scheduling students into special laboratory class-times; or to get one computer into each classroom, with students working in pairs or small groups, and working-time at the computer scrupulously rationed. Circa mid-1980s to early 1990s.

Meanwhile in the business world computers were marching in inexorably — handling accounts, inventories, and customer service. But few homes owned computers. Apart from converts, and experts, and professionals in the IT trade, who would ever need one?

Then, in Australia, Coles Supermarkets and Apple computers dreamed up their supermarket-docket promotion deal, and a lot more schools got a lot more computers, for very little cost. Circa early 1990s, and Macintosh computers began to show a few people, those willing to pay extra for real user-friendliness, just how good a computer could be, and how easy to use.
Hot on the heels of this thin end of the Apple-wedge, IBM realised that DOS-commands were a barrier to widespread popular amateur or non-specialist, non-business home use. The result was the dam-burst of “windows”-style software, with a mouse, and pull-down menus — 1995 — with the new Windows95 user-interface—and people started to think that “PC” meant “computer”.

Incidentally, related to this breakthrough is the cautious interface-sensitive advice:

never trust anything said by anyone about the impact of computers earlier than, say, 1995 … when Bill Gates bit the interface-bullet and shifted the IBM platform to a ‘windows-style’, mouse-enabled, point-and-click working environment (Chandler and Gough 1999).

User-friendliness is a fundamental key to several things about computers and their educational impact, most particularly their curriculum-penetration (their ability to reach into all areas and levels of schooling), and their market-penetration (their widespread adoption by non-computer specialists). Whatever might have been found by researchers when computers were rare, student experience of computers was extremely limited, and computers were hard to use will be irrelevant in a later era, when most students have a lot of experience using computers easily.

Almost as soon as the PC-based “windows-style” work-environment became a universal standard, the next breakthrough was the rapid widespread acceptance of the need to reach beyond the desktop and into the Internet. The short-lived fax-machine revolution of the 1980s was essentially stopped. Fax communication was rendered more than redundant by the ability to send not just a mere paper-image of a document, but the electronic, editable version of the text, or of other kinds of “information”, not just prose. Modem connections which had been a specialist’s option for nearly two decades suddenly became a common or garden feature of computers and computer-use. Although not many people knew what “http” meant, the world-wide web — “www” — and e-mail’s “at-sign” — @ — and the web-site tag “dot-com” slipped painlessly into radio, newspaper, and TV reporting, and even into everyday language. Having your own web-site became a new status symbol. Circa late 1990s.

Given this sketch-outline history, what has been its developing impact on schools? Or on the wider community? Here is one enthusiastic view:

Another student 'reading' Melissa's multimedia presentation on Egypt can select a video 'grab' of the sphinx, with textual information included, or an animation that traces through the archaeological dig of Tutankhamen's tomb with accompanying audio information. More than that, the package can be copied, shared over a network or transported over phone lines from Melissa's classroom to a 'sister class' in Cairo! (Warren 1994 p 14.)

The sceptic in me wonders where Melissa found her video grab, or her animation, or her audio information. It may look and sound great. But it smells just like a project. Select, copy and paste is just the same, whether it is a picture from an encyclopedia, a slab of text from a pamphlet, a video-grab from a video (which Melissa did not make herself), or a copied sound-clip. What remains unclear is whether Melissa learned
more from making this multimedia project than if she had been given a list of
questions to answer, or if she had used real photocopying, scissors and paste, and a
set of trusty Derwent pencils, assembling a traditional paper-based “project”. The
same sceptical caution applies to the idea of asking students to create a web-site
(Gough 1998, p 114).

Interestingly, Lankshear, Snyder and Green remark that:

In many cases, we find that the skills used in research for HyperCard and
PowerPoint presentations [these are both different forms of multi-media-
authoring software] essentially ‘the same, and set up in the same ways’ as
those formerly employed in pen-and-paper contexts … To a large extent, the
substance of the learning and teaching remains more or less the same as we
knew it to be prior to the emergence of these new technologies (2000, p. 95).

Let me say, here, as plainly as possible, that almost anything that can be done or
learned using a computer can be done or learned just about as well (perhaps not as
easily or quickly) not using a computer. Moreover, computers are not a guaranteed
panacea, not a cure for all the problems we face with schooling, and education in the
wider community. Worse still, the ill-considered rush to embrace computers, with
little second thought, endangers non-computer skills, hand-crafts, folk-arts, everyday
human activities and interpersonal exchanges that may all to easily be swept aside as
“old-fashioned”, or “low-tech”.

**Where’s the Critique?**

Having got this far, we are almost ready to disassemble aspects of the guiding
research question. Part of the point of the research methodology of “critique” is that
unless we attempt to disassemble the ideas we are trying to work with, our research
will fail to engage with the situation, and will yield unhelpful results. Alternatively it
may pursue misleading research goals, or produce research data which is distorted by
the unsuspected biases or unexamined assumptions.

It has also been important to make as clear as possible the idea that any attempt to
answer the research question is continually challenged by the rapid changes that are
occurring in computers, their uses, and educational provision or access to them.
Notoriously it is hard to hit a moving target, and this particular research target is
moving all the time!

So: wanting to investigate the impact of Information and Communication
Technology on schooling, it may be helpful to pause, and ask:

- what kinds of information? written? oral? pictorial (static or movie)? aural?
  procedural?

- what kinds of communication? face-to-face? paper-mediated? electronic? voice-
  activated?

- what kinds of technology, especially “hardware”?
  - a static stand-alone desk-top computer?
  - a portable stand-alone personally owned lap-top computer?
  - a work-station, or home-computer, or lap-top with Internet connection?
• a computer with other “extras”, such as a MIDI keyboard for music, or a CD-ROM disk-drive?

• what kinds of technology, especially “software”?
  • wordprocessing?
  • databases and spreadsheets?
  • computer graphics (either pixel-based or object-oriented)?
  • computer programming languages (e.g. Logo, BASIC, Pascal, C++)?
  • mathematics processing packages (aka Computer Algebra Systems, or CAS; including Maple, Derive, Mathematica) or graphics calculator software?
  • music processing or composing software?
  • Internet web-page authoring, or multi-media packages (handling layout of graphics, video, audio, user-interaction, and text for on-line and electronic CD–ROM–type environments)?
  • desk-top publishing software (handling layout of graphics and text for paper-based environments)

• what kinds of venues for learning? ordinary classrooms? computer or other laboratories? libraries? homes? work-place settings?

• what kinds of educational paradigm shifts? changing from:
  • an oral pre-literate, or non-literate culture to a book-based culture?
  • a centralised curriculum organisation to a school-based curriculum?
  • an expository teacher-centred classroom environment to an exploratory child-centred learning environment?
  • a traditional whole-class organisation focussed on a prescribed textbook or curriculum base, to an individualised or small group approach that uses personally negotiatiated learning goals supported by flexible open-ended resources?

So far these questions deal only with ICT. We could develop a similar set of questions about “schooling”, and other non-school learning situations. I am attempting to raise questions, generally, along the following lines, acting as a constructive sceptical critic, a “devil’s advocate” (Gough 1998b):

• what does this term mean?
• what does this term do? or what is it for?
• who does this term apply to?
• what did we have, or do, before this term developed or came into widespread use?
• how different, or similar, is this “new” idea from older antecedent counterparts?
The rise of ICT is not the first major technological change to hit schools. In our life-times we have moved from an era of pencils and ink-pens to ballpoint pens (“biros”, and fibre-tip pens), with a consequent change in the nature of the handwriting curriculum. This is now, in turn, being challenged by the impact on handwriting, and initial literacy, of the increasingly ubiquitous computer-handled alternative to older-style writing processes, namely wordprocessing, with “keyboarding” as its counterpart to letter-by-letter hand-writing, and seamlessly smooth editing of successive drafts of ideas within the one evolving document, contrasted with re-writing and re-typing of a succession of separate hand-drafted versions of a particular “text”. (This is discussed further in Chandler and Gough 1999.)

Vignettes of Successes and Failures in ICT-related Research

Armed with our devil’s advocate questions, what do we find when we start looking at recent accounts of research, and discussions of the impact of ICT on schooling?

Consider, first, the sudden terminological shift from IT to LT, that is, from “Information Technology” to “Learning Technologies”. I have argued elsewhere that “Learning Technologies”, as they are commonly understood, based almost exclusively on wordprocessing and Internet use, leave out many valuable software tools and related skills.

As a result the move to incorporate learning technologies in school curricula and modern work practices does not really change what is currently done. Far from being genuinely new, learning technologies succeed only in slightly extending on existing practice (Gough 2000b). Unfortunately the new emphasis on electronic resources tends to lead students to neglect books, or videos, as important sources. In my own work with student-teachers and teachers I am increasingly encountering students who complain that they can’t find anything on a particular topic they want to investigate. Yet what they mean is that so far their Internet searches have revealed nothing (and it is possible that any web-sites they may have found may lack a sound scholarly basis), and, to me, shockingly, they have not bothered to look at the shelves of books and journals in their university library.

Secondly, consider a recent attempt to research the impact of laptop computers in schools (Ainley, et al. 2000). At this point my comments should not be misconstrued as a wholesale condemnation of this research. As my review shows, at length (Gough 2000a), this is a major investigation, with much to teach us. However it also over-emphasises wordprocessing, Internet browsing and e-mail, and spreadsheets, while neglecting such important kinds of software as computer graphics, mathematics processing software, and music composition software. It also seems to misunderstand and grossly undervalue Logo programming (as in the multi-media package MicroWorlds) as a learning environment which can be used effectively across most areas of the curriculum.

Moreover this important study of Year 7 and 8 classes using personal laptops neglects to gather, or report on any information about previous or existing desk-top computer-access and computer-use at home. This is further compounded by the limited, short-term attempt to gather “control group” information about non-laptop
computer use, and non-computer learning from students who were not included in the experimental laptop classes.

The reality is that, where schools have not yet bitten the laptop-bullet, regardless of the limited school-provision of desktop computers in many schools, many students have access to computers, and, increasingly, to the Internet, at home. School concerns about computer-provision, computer-access, and the development of computer-based skills, compounded by related issues of social equity, culture, and gender, are frequently short-circuited or obviated by the de facto improvised home-provision of computers. Schools generally, and Ainley and her colleagues, ignore this home-provision at their peril if they hope to describe and develop adequate computer skills, at school and beyond.

Thirdly, consider the massive conceptual territory claimed by Lankshear, Snyder and Green, in the title of the study: Teachers and Techno-Literacy: Managing Literacy, Technology and Learning in Schools (2000). The terms “teacher” and “school” may be reasonably clear, at least initially, or traditionally. However as ICT continues to develop, and modify the community, the physical walls of a “school”, and its “library” begin to dissolve. The roles played by a flesh-and-blood teacher in a classroom are extended by the not-so-flesh-and-blood activities of “virtual teachers” — the designers of educational software, information web-sites and interactive CD-ROMs and web-sites, and the on-line programmed “robot teachers” who carry out the designer’s intended instructional interactions.

Against this, of course, schools have never been the sole repository of knowledge, or the sole instigator of learning. The walls between “school” and “community” have always been permeable. Similarly school students have always learned from people who are not trained teachers, just as they have also learned from books, films, and life experiences outside the formal classroom.

But what are we to make of the term “techno-literacy”?

The term “literacy” is problematic, anyway, unless we adopt the traditional view that it refers essentially to being able to read and write. This is often stretched, conceptually, to include “visual literacy” (the ability to understand and make non-verbal diagrams or pictures). Traditional literacy is clearly only part of the essential life-skills that modern citizens need to be able to understand and work with early Twentieth century media, such as film and TV, or with the mixed-media of newspapers and magazines.

But how is the “techno”- part of the neologism invoked, and to what purpose? This is discussed extensively through the book. Suffice it, perhaps, to focus on one example, which I hope may be taken as representative of the limited or even faulty views offered by the authors. Lankshear, Snyder and Green allege that:

In the print era, all instances of encoded information and communication were bounded … [print-era] texts have edges, borders, margins … But with the shift from print technology to computing, and the emergence of database technology, hypertext and hypermedia, we can now ask: Where is the text? Indeed, more radically and unusually, we can ask: when is the text? Also, what is the text? Which is the text and which is the context? (2000, p 38).
At the trivial level of books, covers, pages, borders and margins, this may be true. But in important ways, print-era texts were not really bounded. When one text referred to another (by quote, extract, paraphrase, footnote, reference, parody or allusion) the boundary between one text and another was broken down. You only need to stand in a paper-based library, looking at the shelf of different books on one topic, to recognise the breakdown of text boundaries. No single volume contains the world’s accumulated wisdom on any particular topic: it never has. I felt this myself as a young student when I began to write my own cross-referencing footnotes in the margins of my books: “See also X”, or “This is contradicted / explained / supported by Y”. Similarly an anthology of excerpts that inspires a reader to go to the source-text is a counter-example to such bounding. Consider, for example, the old *Victorian Readers* (1940), the literacy primers of my own 1950s Primary school days. I was surely not the only student who happily found the novels and other sources of the extracts of story, poetry, and non-fiction included in these classic *Readers*.

Also, when a book-text is also a theatre performance, a radio dramatisation, a film or a TV adaptation, or simply a well performed oral reading of the ink-on-paper text, the text is where? Or when? During the film? In the speaking aloud? With the actors on the stage or screen? In our memory of spoken words, moving faces, scenes, events, and feelings? Consider a Shakespeare play, on paper and on stage, or the interactions in a reader/viewer’s experience between Dickens’ novel *Great Expectations* and the David Lean film version.

The hot-link in an Internet web-page that takes an Internet-browsing person from here (at a computer screen, viewing one downloaded web-page) to there (at the same computer screen, viewing another downloaded web-page from a different web-site) is little different from a citation on a paper-page (“This is discussed at length in chapter W”; or “See Bloggs’ alternative argument in U”) that links across the boundaries of margin, page, chapter or book, or the book-cover illustration of a filmed version of a novel.

Taking this only slightly further, Lankshear and colleagues argue that we live in an age that values “information” over “knowledge”, or other aspects of communication:

> deep [in] the realm of values, norms, priorities, goals and purposes, and identities … [in] many ways, the text paradigm was the literary text, and essayist writing dominated school literacy. However … we now see … the separation of text and information … [and need] to view literacy as involving, and even requiring, the integration of text and information … [challenging] traditional ways of thinking about literacy that … [see] information … as subordinate … [or] secondary to ‘understanding’ or usage (2000 p 39).

Fortunately they later redress this apparent view by including amongst their “principles of technorealism” the aphorism: “Information is not knowledge” (2000 p 147). Certainly if their experience of school and “literacy” was like mine, and perhaps yours, the English teacher did spend time on “writing compositions”, and we read a lot of fiction. The “literary text” was a major focus for study and practice. But surely
it was not the only focus. We also learned how to handle “non-fiction”, to write technical reports, and formal letters, and how to make notes from the blackboard or our textbooks. That is, “non-literary texts” were also a major focus for study and practice. Information was just as important then, as it is now.

Lankshear and his colleagues’ discussion is not helped by their Figure 3 (2000 p 40), which consists of two perpendicular lines (axes, perhaps? but there are no arrowheads to indicate this). One line is labelled Text at one end, and Information at the other; the other line is labelled Technology and Language at opposing ends. I find this diagram quite confusing: as a visual literacy sign or symbol it is hard to “read”. It suggests that we have two poles, or axes, and that “Text”, for example, is in some way an opposite of “Information”, while “Text” is also separable in some way from “Language”.

For me this figure (and the related discussion) is baffling. I cannot imagine how I could have a text (whatever that might be, and Lankshear and his colleagues have an extremely flexible, if not outright vague definition of “text” which includes more than printed material: p 62) which does not contain some kind of information. (Of course we could resort to the Dadaist nonsense-poetry using random letters and invented meaningless syllables, and say that this is “text” which is free of “information”. However the Dadaists had an information-related point to such a radical and ultimately pointless literary/artistic innovation. I doubt that is what Lankshear and his colleagues might have had in mind, if, indeed, they really have some coherent way of explaining this figure.) Equally, I find it impossible to imagine that I could have a piece of information which could not be construed as some kind of text, even if it is (as they suggest it might be) a spreadsheet, or part of a database filled with categories and numbers.

Meanwhile I find that “language” runs inseparably through text and information. Equally I find “language” inherent in “technology”; and, vice versa, there is “technology” inherent in certain forms of language, or language representations. To their credit, Lankshear and colleagues emphasise that

Written language is always already technologised, in the sense that it comes into being only in and through available technologies of information and communication — such as marks on natural surfaces, the alphabet and other symbol systems, stylus and pencil, the printing press and, today, the ‘digital electronic apparatus’ (2000 p 25).

But if Lankshear and colleagues are misguided in their description of the differences between old-style book-based learning, and old-style literacy (and elsewhere in their arguments they seem to misunderstand how people read, and how they express themselves through writing), can we accept their radical views of the ways new technologies change our uses of books, information, and “literacies”? Only if we very carefully critique their arguments, their examples of supposed good-practice, and their suggestions for modifying current school practices. Very carefully! Some of what they say, after much critical sifting, can be shown to be sound, and valuable. Elsewhere they are wrong, unhelpful, or misleading.

Fourthly, even where we can clearly identify a change in the school, such as having a computer in a classroom, or even a row of them, or a laptop for each student,
does this make a difference, compared with the pre-computer situation? As a possible example, most classrooms now have a computer, which may be connected to the Internet. But, it is important to ask whether that really changes the essence of what the classroom would consist of if the computer and Internet connection were not there? (This, and related issues were discussed in Chandler and Gough, 1999).

Much as I enjoy a good web-site, I am not sure that I have yet found one that is better, for learning, or as a source of information, than a good book on the same subject. Similarly, no matter how constructively and sensitively interactive a web-site, or learning software package, or interactive instructional CD-ROM may be (and some are quite good), they lack human warmth and sympathy, and they are only as good as their underlying programming, or their underlying human programmer(s). They cannot respond to a student’s important side-tracking interest, or frustration, or a sudden, unpredictable, creative inspiration.

Similarly, consider the writing process, shifting ideas from inside your head (in so far as we can reasonably say that the ideas are there, before they are manifested elsewhere) out onto paper or a computer screen. Research on “text-drafting” or the “psychology of composition” — the process and thinking when one use wordprocessing on a computer — suggests that the computer is a mind-tool that enables a writing-drafter to work quite differently than if the person was using pencil and paper. Maybe. What do you think?

Whether a text is wordprocessed or hand-written, regardless of the surface-level cosmetic features of spelling, grammar, and text-legibility, the real test of the compositional process is the expression of clear ideas. That depends on the human brain behind the composing. Being able to wordprocess will, in itself, do nothing to improve on what the brain can do. That is, wordprocessed documents are likely to be technically more correct and cleaner, but they are unlikely to be better as pieces of written/composed expression by an author. Wordprocessing does not, in itself, guarantee clearer thinking. It does not work as a thinking tool, except that it may make initial drafting and on-the-run editing easier (Chandler and Gough, 1999).

Finally, consider the much hyped Internet, that is, the agglomeration of web-sites that can be electronically “visited” by computer-users with a modem-connection, suitable web-browsing software, and an Internet service-provider, is little more than a vast Earth-spanning electronic library. However, unlike most libraries which consist of commercially produced paper-based (and other) materials, these web-sites, these electronic books, can be “published” or offered on the Internet, by any bozo who can afford the cost of making such a web-site and the cost of “mounting” it, using his or her computer-plus-modem-connection, or hiring the services of an Internet provider.

A commercially published paper-based book (or video) is editorially checked for quality, accuracy, and morality. This is never a guarantee that, just because something is seen in print, it can be wholly believed. One of the most important goals of education is to develop students’ ability to critically evaluate whatever sources of information they encounter. Faced with a massively ballooning heap of web-sites, few of which have any editorial checking for quality, truth, or accuracy, this is
increasingly important. That is, book-sifting information-analysing skills are exactly what students need when they start looking at web-sites, because students need to learn to think critically, in all situations (paper-based, electronic, and live-action human), and because web-sites are largely equivalent to “electronic books”. (This is discussed at greater length in Gough 2000b).

**Conclusions?**

A revolution is occurring in the working lives of most researchers and educators. The revolution is having an increasing impact on the “customers” of these researchers and educators, that is, on the larger school community as a whole, students and parents alike. This revolution is also occurring on the desks of researchers, educators, students and parents. For us, as participant-observers, a reflective, critical self-study, bolstered by constructive scepticism, seems apt.

You, my reader, might then pause a moment, and ask yourself how much your own present job, as researcher and academic, would be changed, tomorrow, if you no longer had free use of computer, printer, software, and Internet access to e-mail and web-sites. Certainly academics and researchers managed, years ago, without these aids. As I have noted, anything (that is, almost anything) that can be done with a computer can be done just about as effectively without one. Nonetheless having computers, and, more recently, the Internet as a medium for communication and a source of information, helps us do our job. What has been the impact of computers and the Internet on us?

Sometimes as I struggle to make sense of the discussions I find myself involved in, or the books, articles and web-sites that challenge me, I feel like an outsider, an observer, not one of those differently active ones who conduct the active data-generating of more familiar kinds of research. The parade goes on, regardless. I watch, and wonder. I try to be active in my own ways.

Now that I try to sum up what I am hoping to do with these remarks, I am reflecting, critically, on my own processes of critical reflection — a process of meta-analysis, or meta-critique.

Looking back at some of my past efforts I feel that I have been doing little more than endlessly chipping away at the same old block. I can re-express this, speaking of chipping, in the immortal words of Don Chipp (the Australian politician who became disenchanted with the two dominant political parties, and decided to inaugurate a third alternative party) — I have been trying “to keep the bastards honest”.

Expressing this more allusively, I am continually asking: what is the emperor wearing?

Intellectual gad-flies are needed now like never before!

**References**


Conceptual Testing, Reality Checking, and Constructive Analytic Criticism in Research Planning and Evaluation: A Case Study on 'Computer Impacts on Curricula'

Paul Chandler chandler@deakin.edu.au
John Gough jugh@deakin.edu.au


Abstract
Effective research depends on clear definitions, and arguments, which have obvious plausibility and fit reality. But this is not always easy to establish. Sometimes earlier researchers have worked with unclear definitions. The technical terms being investigated in research may in practice be widely and diversely used in non-research settings. It can also happen that, quite independently of what the research community is attempting to investigate, the real world marches on regardless, surrounded with a certain amount of confusion, media hype, and political bravado. Education generally, as a field for research, is a topic that everyone knows something about. Research ideas bloom and wither. Cultural and technological changes in society and education result in uncertainty and confusion. In this setting, research methodology needs to be firmly grounded in sceptical, hard-headed common-sense. Any definition proposed for research needs to be ‘tested’: What does it mean? How do we know this? If this is what is meant, then what are the obvious consequences? If this is what is claimed, does it correspond to what is commonly reported? The outcome of careful scrutiny of research topics, tested by critical analysis, and checked against actual circumstances, can often be a clearer framework or picture of what the research might realistically be able to investigate. A short case study is discussed, in which these methodological approaches are brought to bear on the research topic ‘Computer Impacts on Curricula’.

Introduction
In principle it has almost invariably to be accepted that brand-new weapons, particularly those of revolutionary design, need a small battlefield trial; that to place reliance on sheer novelty to win battles is to despise the enemy since only if a novel weapon is really adequate in concept will it survive repetitive use in battle. A weapon’s ultimate test of durability is its capacity for improvement by the intellectual evolution of its basic characteristics and the integration of each improved model into the changing strategical and tactical concepts of practical soldiers. (Macksey 1976 p 36).

With the comparatively recent advent of mouse-driven ‘windows’-style user-friendly interfaces, pioneered by Macintosh, and imitated on the IBM platform, we have moved from the ‘small battlefield trials’ of the early clumsier days of the single stand-alone computer in an otherwise ordinary classroom. Now we routinely accept the idea that a student’s work-station is an individually ‘owned’ computer, and many schools may soon pursue the laptop options that so far only a few schools have experimented with—very successfully! The ‘intellectual evolution’ of the computer has now resulted in it being an indispensable tool for almost all school work, except the unreplaceable human performance classes of Dance, Physical Education, Instrumental Music, Drama and crafts such as Cooking and Woodwork. It is time for all teachers to...
consider the ways that computers may be ‘integrated’ into the ‘strategical and tactical concepts’ of classrooms that have hitherto relied on the battle-hardened technology of textbook, blackboard and pen (plus or minus a bit of video, and audio).

But almost as soon as we state our concern, as a research question—such as ‘What is the impact of computers …?’—we face conceptual difficulties that need careful analysis. What do we mean? Even the seemingly clear use of a word such as ‘computer’ needs careful analysis of real situations and uses. Can we draw on early research and hope to find anything of enduring value from the experimental pioneering days of mouse-less stand-alones? What ‘curriculum’ do we have in mind? How effectively can we isolate school-experience with computers from home-experience, especially at a time when schools are still not able to provide as much personal computer access as many students enjoy at home?

Cautious, critical, sceptical devil’s advocacy can make an important contribution to the early stages of this research endeavour (Gough 1998). In the end, what can be established by the analysis may be little more than common sense, perhaps. But what is revealed by the careful analysis is not immediately obvious, and the sense is, perhaps, not all that common, awash, as we are, with media hype, inflated and mis-directed expectations, and unsubstantiatable claims of what computers are, supposedly, or allegedly, good for.

What is the impact of computers on the school curriculum?

In classroom-based research, there may be a tendency, as Doyle and Ponder (1975) pointed out nearly 30 years ago, to be disproportionately concerned with teacher behaviour compared with other elements of the classroom ecology (that is, the network of connected processes and events which impinge upon classroom behaviour). Currently we also need to start attending to recent silicon-based classroom innovations which act as substitutes for teacher behaviour, which typically involve computers, software and electronic computer-mediated communication (including electronic document exchange, e-mail, Internet searching and downloading, and student-software/web-site interactivity).

The very existence in classrooms of computers, with or without Internet connections, the arrangement of the classroom, the impact on student behaviour (e.g. discipline issues) and the impact on curricula and possibly on cognitive processes (e.g. the challenge posed by wordprocessing to the traditional handwriting curriculum, or by mathematics processing software to the algebra curriculum) impinge on teachers’ pre-planning and classroom action.

As Postman and Weingarten (1969) argued, 30 years ago, a change in an environment is rarely additive or linear. You seldom, if ever, have an old environment plus a new element. You have a totally new environment requiring a whole new repertoire of survival strategies. In no case is this more certain than when the new elements are technological (p. 20).

Of course, thirty years later it is worth asking whether the environment of schooling is actually all that different from the mid-60s Postman and Weingartner were discussing.
That is, now that Postman and Weingartner’s technological and institutional future has arrived, is it really different in substance from the 1960s-present about which they wrote? Cable TV and video, for example, may not be all that different from the TV they had seen as a challenge to book-based culture and traditional teacher-centred book-based schooling. Even where teachers have embraced the use of TV in classrooms, if it is the teachers who choose what is watched, and when it is watched, and who ‘host’ or ‘compere’ the resulting classroom discussions of what has been watched, perhaps the book-centred methods are actually only slightly altered by some partial substitute by broadcast, cable and video.

Postman and Weingartner also remarked that, ‘As Father John Culkin of Fordham University likes to say, a lot of things have happened in this [Twentieth] century and most of them plug into walls’ (1969, p. 19). While the image of new things all plugging into walls is catchy, it actually misses some important points. Almost all of the labour-saving devices that plug into walls, that is the electrically-powered ones, actually have their hand-powered, steam-powered, water-powered, or animal-powered counterparts that preceded them in the Nineteenth century. Certainly we live in an age when, thanks to devices that plug into walls, we don’t have to spend Mondays doing the family laundry, and Tuesday doing the family baking. But the most important devices may be those that allow us to communicate and receive information. The quantum jump in culture that marks the Twentieth century is less the fact that modern devices run on electricity, than that they transmit and receive information—albeit, slightly anticipated by global telegraph cabling in the Nineteenth century.

The real point is not one of splitting a few historical hairs about links between industry, technology and culture, but to emphasise that the important ‘plugging in’ is the telephone line with modem, aided by global satellite networks. Moreover it serves to highlight a further quantum leap in computer-use—from stand-alone to networked!

**Computer/Technology Curriculum Impact: Example 1**

As a possible example, most classrooms now have a computer, which may be connected to the Internet. But, it is important to ask whether that really changes the essence of what the classroom would consist of if the computer and Internet connection were not there?

A teacher who knows and controls and leads, supported by information resources and teaching materials, delivering education to a group of students who do not know so much and are in the classroom precisely for the purpose of doing what the teacher wants them to do … the current classroom may not be that different from a 1960s classroom.

**Computer/Technology Curriculum Impact: Example 2**

One intriguing example may highlight this further. Those of us who grew up with the idea that ‘literature’ equals ‘books’ (augmented by live theatre, and its celluloid and TV counterparts), have now accepted that Literature at school can expand to include the study of, say, Eisenstein, Kubrick, Frankenheimer, and Spielberg, alongside Dickens, Shakespeare and Keats. However with the rise of computer games, Catherine Beavis has urged school Literature teachers to consider setting a computer
game for study, alongside books and film (Sinclair, 1999 p 12). Beavis offers ‘Abe’, the computer game hero from the game *Abe’s Exoddus*, set in the computer game fantasy scenario-world known as Oddworld, arguing that Abe is a leader-saviour character who can be compared with Oscar Schindler, a real person in history, and central figure in a Spielberg film and a book by Thomas Kenneally. Beavis suggests ‘you might spend one period a week playing the game and another two or three writing about it’ (p 12). She argues further that ‘definitions of literacy are changing and kids need to be visually literate as well as verbally literate’ (p 12).

But despite the apparent shift, from book or film, as focus of study, to computer game, the literary study is remarkably unchanged. ‘Looking at themes, sources and how a text [in this case, a game-scenario mixed with actual game-experience] is constructed, whether it’s a novel or a game … [is] directly analogous to the way you might be looking at it in a poem’ (p 12). Beavis points out that ‘computer games are a lot less exotic than they’re sometimes shown’ (p 12). However, whether they deserve such study (except, as Beavis suggests, as academic bait for boys who might otherwise be weak and reluctant students), and whether they can stand up to the cultural comparison with accepted literature, remains to be seen. The point being made here is that the curriculum is essentially no different, only the grist for the curriculum mill.

**Computer/Technology Curriculum Impact: Example 3**

Consider a different classroom example. In the 1960s the curriculum content and purpose was, typically, dictated to teachers and students by an external governing body. By contrast the curriculum content of some current classes is developed by negotiation between teacher, student and school community. This de-institutionalising, or freeing of who is in control had been one of the radical anti-authoritarian changes argued for by Postman and Weingartner—one that has been, at least sometimes, introduced. However it has little to do with technology. It is a societal change.

If Postman and Weingartner’s remark (aimed at a global, societal level) is translated to the level of the classroom, it implies that a computer is not a mere ‘add on’ to existing teaching, but is likely to bring with it some fundamental change. This needs to be carefully analysed.

**Computer/Technology Curriculum Impact: Example 4**

In the 1970s we allowed students to use their hand-held scientific calculators, as their calculation-facilitating tool of choice. Mathematics teachers were thus able to drop the use of logarithm tables and/or slide rules from Secondary mathematics. But this did not bring about a significant change in the mathematics content. Logarithms and trigonometric values are still taught, albeit for slightly different reasons as regards the continuing teaching of logarithms. Previously logarithms were introduced initially for the sake of easing computational difficulties. They were also introduced also as development of scientific notation and as a step towards a new kind of mathematical function. Logarithmic and exponential functions were different from linear and polynomial algebraic functions. They were used later in carrying out log-log simplifications of non-linear data, and also in differentiation and integration. Now
logarithms continue to be taught, but only for the purposes of mathematical functions and data simplification. But even though their teaching is facilitated by the log/antilog button on a calculator, they are still taught, around the same stage in the curriculum, and in about the same way.

**Does the addition of a new technology really change the old curriculum?**

Postman and Weingartner’s argument is not based on the nature of the technology (which in this paper is taken to be the computer, plus Internet: the relevant computer issues will be discussed shortly), but simply on the re-arrangement of the pre-existing technology of the classroom. Olson (forthcoming) has argued that

In classrooms, computers encounter a pre-existing technology: the techniques and tools of classroom instruction and management which use familiar and predictable resources and routines lying readily to hand and embodying certain values about the work that is being done. Desks, boards, books, chalk, maps, and more are where they ought to be and do what they should … although teachers may not be able to give a full account of their technology, they are well aware of the risks of abandoning familiar technology.

Thus, it is argued that the introduction of computers into a classroom represents a fundamental dislocation from the known environment, where new routines must be developed to manage the new range of available technologies. Educators need to discuss the physical environment of the mixing together of computer-laboratory and pre-computer-classroom, and the changes this will bring for teachers and for the pedagogy use within it.

Incidentally this reference to Olson’s forthcoming article suggests a timely word of caution. We do well to distrust anything said about the impact of computers on education which was published earlier than the early 1990s. Any discussions earlier than that are commenting on a time when computers were so rare and so clumsy, by comparison with user-friendly ‘windows-style’ environments, that people at that time could only try to guess what might happen, if computers did become more widely used. At that time the evidence of what was actually happening applied to what could only be described as, at best ‘experimental’ situations, which were so unlike non-experimental situations that the discussion of ‘computer impact on curriculum’, while interesting at the time, could only be speculative.

It may be noted, in passing, that Seymour Papert (as in his epochal book *Mind-Storms* 1971) is one of the few, from those early days whose vision seems to stand up to later scrutiny. But, notably, he created an open-ended interactive environment in which student action and thinking necessarily had to change—although what he offered was only an extremely user-friendly design-brief for the kinds of things that competent computer programmers were already doing with programming languages such as FORTRAN which were far from user-friendly. Just as interestingly, Papert’s model for user-friendliness was partly developed from Piaget’s ideas of child development and the flexible interaction between student, clinical interviewer and provocative instructional material.
Hand-writing curriculum and new technology

However, as soon as we start to examine specific cases, the impact of computers on pre-computer curricula are extremely variable. The shift from handwriting with a pen on paper to typing with a keyboard is a massive change to the hand-writing curriculum. We may soon find, as increasing numbers of young children, who are already keyboard-literate, start school, that the reason for them to start acquiring hand-literate skills may be a matter of aesthetics, craft-oriented conservatism or fundamental survival skills. For example, how do you ‘write’ a message when your computer is broken, or you left it at home? But the major impact is that computer-skilled students who set out to learn to hand-write may already know how to keyboard-write. This means that much of the learning to read skills and meanings which proceeded in tandem with the older hand-writing curriculum will have already been learned.

Hand-drafting and the new technology

This change in the traditional hand-writing curriculum may be contrasted with learning to express ones-self in writing—getting ideas out of the head and into a wordprocessing document. The writing-composition curriculum may undergo more of a cosmetic, less of a radical change, if the general process of ‘writing’, or written-self-expression remains unaltered by the move to use wordprocessing as the self-expressive tool of choice, albeit, improved in ease and efficiency. For some people, trained in the earlier hand-writing era, the process of written composition may be effectively unaltered, whether they draft by hand, by typewriter, or by wordprocessor.

Of course, we still need, and will continue to need, all these skills: to be able to hand-write, as well as to hand-compose, and to wordprocess.

It is also unlikely that the imminent advent of universal voice-recognition software will alter this. It is well known, by anyone who has attempted to transcribe a tape-recording of spontaneous speech, that the way we speak our ideas, off the cuff, always needs extensive editing before it can stand as written-expressed material. That is, unless computer software becomes so intelligent that it is able to edit our oral utterances into smoothly write-drafted prose, we will still need to have good hand-drafting or text-drafting and editing skills. At this point we can anticipate a conservative approach to traditional curriculum, or curriculum of tradition, comparable to the conservative movements to preserve ancient hand-crafts (e.g. thatching, hedging, knitting, bobbin lace, calligraphy and hand-weaving), non-electric and live-music, and Slow Food. Like the world’s species gene pool, we need cultural and curricular diversity in the interests of richness, sustainability, and creativity.

Note here the possibly clumsy way that newly-linked words need to be developed in the search to understand the impact of new technology. Aspects of the curriculum, such as ‘writing’ which had been well understood now need to be re-expressed, in order to distinguish the way things used to done, and new, similar, but subtly different ways we do the same kind of thing, using the technology, while also continuing to learn and use the pre-computer methods. That is, ‘writing’ is no longer just ‘writing’, and ‘hand-writing’ is only one way of getting letters onto paper. We need words that describe other ways of getting the words out of our heads and into print.
Dislocation at the Level of the Individual Learner

Galbraith and Haines (1998 p. 279) comment that the physical separation of the learning components (pen and paper, computer screen) and the human brain add a particular dimension to the co-ordinating processes required for effective learning. They point to research which suggests that unfamiliar technology can cause special difficulties even when the tools are primitive (e.g. ruler and compass). Of course this is true. Pre-school students who have never used a pair of scissors may find them extremely difficult to handle. By contrast, in old age, Henri Matisse used scissors as fluently as he used more ordinary artists’ tools, as a means of ‘drawing’, that is cutting outlines of images, or ‘sculpting’ with two-dimensional colors.

Temporarily ‘special difficulties’ arise because of the novelty of the tools, perhaps because the tools are themselves genuinely new, as tools. We only need to cast our minds back to our own first experiences with databases and spreadsheets—one of the newest tools which is genuinely different from almost anything which previously existed for carrying out similar data-handling tasks. Only those few among us who were already used to routinely manipulating card-systems of data, or to using programmable calculators, would have found databases and spreadsheets immediately sensible. By contrast, computer software which mimics tasks and tool-use which are already familiar are far easier to handle. Consider the comparative ease with which many of us were able to begin using wordprocessing or computer graphic packages, using the computer-mouse as a graphic-pencil. Compare this with the learning challenge presented by a first programming language, which is a kind of information processing tool, such as FORTRAN or COBOL.

Alternatively the ‘special difficulty’ may be simply because the tools are ‘new’ for the learner. That is, the learner has not yet internalised and automated the processes of using the tool. Give a child a pogo stick, a two-wheeler bike, a Lego kit, a typewriter, a set of lino-engraving cutters, or any tool, and, initially, the student will handle the tool clumsily, with little fluency or insight, step by step, deliberately, hesitantly. But with practice the student will find easy ways of doing what the tools allow, intuitively, naturally. The tool becomes an extension of the hand, which is, itself, a fluent extension of the brain. The same thing is seen when a student starts to learn to play a new board game. At first each move is painfully laborious, and the student cannot see even the immediate next-step consequence of any move that the student might make. But with practice and enough experience the student begins to mentally plan ahead several alternative paths of action, anticipating the likely responses of the opponent.

The Nature of the ‘New Thing’ in the Classroom

It is important to recognise the move to a computer laboratory may be a fundamental dislocation from the known environment and resources. It is also important to consider the characteristics of this ‘new thing’, as it has some fundamental differences compared with desks, boards, books, chalk, maps and even overhead projectors, video players and other technologies. Dickey (1998) has said that one constantly hears the computer referred to as a tool, as though this were reassurance of some sort. It is reassurance only until one
remembers how the tool has shaped the human hand, and notes with a shock that this tool is shaping not the hand but the mind. A tool used as extensively as the computer cannot help influencing how we think (quoted by Williams, 1990, p. 18).

What Dickey says sounds smoothly plausible. But is he right? Is he saying anything of any substance? In what way does ‘the tool shape the human hand’? If he means that the builder, plumber and gardener get callused palms from digging with pick and spade, and the dedicated hand-writer gets callused finger-joints from wielding a pen, this ‘shaping’ of the hand is trivial. This talk of shaping the hand is not what tool use is about. Instead what the tool does is to make it possible for the human hand to do something new or differently as easily as moving a human hand. Consider the use of levers and hydraulics to drive a bulldozer, crane or bobcat. The hands of a bobcat driver (and a bobcat driver’s child) are basically the same as anyone else’s hand, give or take a few calluses.

What, then, about Dickey’s shocking claim that a tool changes the mind? First, is there any evidence, in human history, literature, or art, that something we think of as amazingly new has not been anticipated by creative minds decades or centuries earlier by people who did not have our tools available? The fax machine, for example, was patented in the mid-Nineteenth century, but was neglected because Samuel Morse’s new code for alphanumerics was a runaway success, when allied with the simple On/Off technology of telegraphy. What comes first: the tool, changing the mind? Or the mind, imagining the tool?

Second, why not try to look for evidence that a new ‘tool’ has changed the human mind. Although it is impossible to present any hard evidence of the effect of the invention of writing (has there ever been a bigger more epoch-shaking invention?) on the human mind, we can speculate unscientifically. Doing so, it is unlikely that even something as significant as moving from oral pre-literate to literate culture changes the nature of human thinking, or what it means to be human. On the other hand, we are ourselves aware that the way an argument is presented, orally, may be different, in important genre features, from the way it would be presented in writing. But beneath the surface differences of the two modes of argument, the thinking remains effectively the same, because the tool, which represents the thinking, is language.

Take a different example: a symbol-tool, such as algebra, can make different kinds of thinking possible, different, that is, from wholly verbal thinking, or the geometry-based reasoning used by the Ancient Greeks. But this is hardly compelling evidence that Archimedes’ mind was different from ours, because he used geometry and we used algebra. However, at a trivial level, having a calculator available to handle pesky arithmetic, can mean that we no longer need to know as much about, say, logarithms. Similarly the multiplication tables, from 1 x 1 to 9 x 9, with place-value ideas, may be all we need in our decimalised post-pennies and shilling era. Similarly, a good wordprocessor can lessen the load on a writer’s mind. The writer can search for whatever is to be ‘said’ in a more relaxed way, knowing that whatever is typed, however roughly, can be edited at leisure. When you are able to see what you say, you know what you mean, perhaps (as Graham Wallas put it: quoted in Cohen and Cohen 1960), and being able to see it more easily, or with less anxiety about being right, first
time, can be a help. This, perhaps, is the way that literacy skills alter oracy performance—the alphabet-as-tool changes the human mind.

That is, Dickey sounds good, but means very little in practice. We need a reality-check, against which to test the rhetoric.

A wide body of literature relates to teachers’ deliberately choosing to use computers for various cognitive tasks (e.g. Logo, computers in maths, simulations, etc.). However, the literature on ‘text-drafting’ or the ‘psychology of composition’ (to borrow a phrase from Gibbons: 1988, although ‘composition’ is such a widely used term that research journals use the word in their titles)—the process and thinking when one use wordprocessing on a computer—suggests that the computer is a mind-tool in a more fundamental way than choosing to use it for certain cognitive tasks.

Indeed, this is an interesting speculation which could lead to valuable research into possible impact of computers on the ‘psychology of composition’. But it is also important to ask—composing what? Does Gibbons mean ‘drafting prose text’? What about composing music? Sketching? Sculpting?

Here the phrase ‘psychology of composition’ arises from a consideration of wordprocessors and the writing curriculum, and a considerable early speculative literature discusses this type of software and its use. Daniel Chandler (1992, pp. 180-181) argues that writing by hand is very different to writing on the screen. He argues that there are more steps involved in preparing to use a wordprocessor than there are in picking up a pencil, and therefore that the writer can feel managed by the technology, and as a result the quality of writing suffers because technique becomes more important than feeling.

Against this, a word of caution: never trust anything said by anyone about the impact of computers earlier than, say, 1995. That was when Bill Gates bit the interface bullet and shifted the IBM platform to a ‘windows-style’, mouse-enabled, point-and-click working environment. Before then, Daniel Chandler may have been right, in part, although this seems unlikely. Many of us had begun wordprocessing in the early 1980s. But this often occurred, for some of us, after first becoming reasonable adept at composing directly at a typewriter, and for others, after developing reasonable hand-drafting facility. It is possible that Daniel Chandler had a good secretary who did all his typing for him, possibly from Daniel’s tape-recorded dictation, and he had not developed any keyboard-related drafting or composing skills. If he had already become a fluent typewriting-drafter, then, like any other keyboard-using adept, he would have taken to even the clumsiest pre-‘windows’ wordprocessor like a duck to water. If typing, that is, using the QWERTY keyboard, is the hurdle or barrier to fluent use, then researchers should say so. But good wordprocessing software requires little more than a shift in the process of fluent automation of letter-selection, from mind-hand-writing selection used in manually spelling, to mind-finger-keypressing selection used in typing.

Yet, there are many scholars who would argue that the psychology of composition is changed for the better rather than the worse. Hartley (1993) considers that research into wordprocessor use predicts that there will be more drafting, longer texts and texts of better quality. At first glance Hartley’s arguments seem more reasonable than
Gibbons’. Certainly wordprocessing, well used, should result in better spelling, better grammar, and gloriously readable printing. Documents may be longer, but, in itself, this is not a measure of quality! However, whether wordprocessed or hand-written, the end result, behind the cosmetic features of spelling, grammar, and text-legibility, the real test of the compositional process is the expression of clear ideas. That depends on the human brain behind the composing. Being able to wordprocess will, in itself, do nothing to improve on what the brain can do. That is, wordprocessed documents will be technically more correct and cleaner, but they are unlikely to be better as pieces of written/composed expression by an author.

Hartley notes that the literature is not conclusive, and that the effect due to computer use is hard to distinguish from effects due to other aspects of the instructional environment. Mullins (1988) argues that wordprocessing ought to structure the user’s attention so that a particular revision strategy is adopted and makes the non-linear evolution of piece of writing accessible.

There is no shortage of empirical evidence of a change in the psychology of composition. In a study by Lutz (1987), it was found that the interaction between human and machine appears to influence the writing process itself—the cognitive strategies used by both professional and experienced writers differed when using pen-and-paper compared with computer technologies. Daiute (1986) found that the writing instrument (in this case the wordprocessor) can effect the writing process. Jenkins (1989) observed changes in her (Secondary) students’ writing over the years in which she used a wordprocessor in her writing classes. Whilst the changes in the content, genre and organisational of the work might be attributed to other factors (e.g. students increasingly living in a ‘video age’), Jenkins makes the important observation that the word processor allowed her students to work with groups of words which are ‘chunks of meaning’ rather than individual words or letters. However, importantly, student access to computers for this work is a crucial factor, which is likely to have been comparatively limited in 1989. Compare the hand-drafting access of laptop-equipped students with those who rely on a computer at home, or in a school laboratory.

Perhaps much of this pre-1995 research literature consists only of ad hoc analyses of introspective self-reporting by researchers and those few undergraduate and well-endowed school student guinea pigs who had access to very early desk-top computers for perhaps one hour a day. We might well ask, now, where is the research on the impact (not simply descriptive accounts of the everyday use) of laptops on writing? Or is it too late to attempt to investigate the changes that result from implementing a laptop program? Is it all now so commonplace and taken for granted, and everyone thinks that research question was answered in the pre-‘windows’ 1980s, so that now no-one is bothering? Importantly, for research, there are no longer any really adequate control groups. Even in schools without laptops, students at home have hours per day of access to their home computer, if they have a big enough and serious enough writing task to undertake. So we would be reduced to trying to make speculative comparisons between descriptions (a la Donald Graves) of the pre-computer hand-made writing process, and the present universal reliance on wordprocessing for almost all pieces of writing except jotted notes and holiday postcards.

Two types of software can be thought of as extensions of the use of wordprocessors for composition. Firstly, there is the use of electronic mail to support student’s
communication with distant audiences. Cohen and Riel’s (1989) research shows that this technology can support a functional writing environment, which in turn can lead to improvements in the quality of students’ writing. However, approaching this research, with retrospective curiosity, several important questions need to be asked. How user-friendly was the software? How globally wide-ranging were the addressees in this pool of e-mailing research subjects? How many hours per day on computers were spent by these early e-mailers of the mid-1980s? Similarly, what criteria were used in their comparisons that showed ‘improvements’. Do Cohen and Riel mean, ‘improved and therefore better than’, or do they mean ‘these students weren’t so good and later, perhaps thanks to using e-mail, they were better’? Were there control groups? Did the control groups (or a hand-writing alternative treatment group) also engage in snail-mail or phone communication? This kind of early descriptive would-be research needs a gruelling examination. Perhaps little of it would stand up!

The second type is multimedia software. Tierney, Kieffer, Stowell, Desai, Whalin and Moss (1990), in a longitudinal study, noted shifts in the psychology of composition when students used multimedia software over a long period of time, including changes in:

- approaches to the development of documents;
- how knowledge may be represented via multi-layered and dynamic graphic interfaces; and
- experimentation, for accessing ideas and thinking through topics.

However it may be worth asking here, just what multi-layered dynamic graphic interfaces were available in the late 1980s for a longitudinal study: menu-driven software? touch-screen software as in the PLATO system? or Macintosh HyperCard, which in many ways was the shape of the future we have now inherited?

There is a sense in which long-term exposure to wordprocessing (and similar) software gives rise to alternative cognitive processes. Whatever the agenda for change a teacher or school might have is relatively unimportant because such changes will tend to occur, to some extent simply through use. Moreover, because computers are also widely used in the adult community, the use of wordprocessing (unlike, say, the use of Cuisenaire rods for Primary mathematics learning during the 1960s in Victoria) in schools is supported by the general community, which is, itself, changing in response to computers.

Interestingly, Galbraith and Haines (1998) studied computer use in the teaching of mathematics. They note that computer attitudes are more influential than mathematics attitudes in facilitating the active engagement of computer-related activities. Whether the usual algebra curriculum, for example, will need to be modified in response to the increasing use of mathematics processing software as a tool for learning, and a tool for doing mathematics, is already being discussed (Stacey 1998). But the future impact of computers on the mathematics curriculum is far from clear, and will not become clearer until a school-generation have worked with the tool.

**Challenges to Future Research**

Further research needs to consider, very carefully, what software is being used, within what aspect of an otherwise ordinary(?) school curriculum. Software possibilities include:
• Logo programming;
• spreadsheets;
• programmable calculators;
• graphic calculators, or graphic calculator software on a full-size computer;
• geometric processing software (such as Cabri Geometry); or
• mathematics processing software (a.k.a. computer algebra systems or CAS—e.g. Maple, Derive, Mathematica).

This research should also consider computer-curriculum linkage, such as:
• computer-assisted instructional and practice software;
• computer-based mathematics practice games; and
• multi-media teaching and research and resource packages (e.g. CD-ROM ‘museums’ and ‘laboratories’);
• and, also, using:
• Internet as a static resource for learning materials;
• Internet as a source of student / web-site interactive experiences; and
• e-mail and listserv interest groups as motivation and support.

Researchers will also be interested to know what computer-access the students had:
• only at home, shared or personal;
• laptop, taken anywhere;
• stand-alone or singles in an ordinary classroom; or
• working on mathematics (or other ‘typical’ (?) school subjects) in a one-to-one student-computer computer laboratory.

The final twist is that, if the Internet continues in the way it has recently begun to develop, Internet access, not just computer access, will also be a major factor with its own impact on curriculum, learning, and working methods. But can even a developed country, such as Australia, afford the real costs of ensuring that any student, anywhere, can use a computer and also dial up the rest of the world? Not only are recurrent hardware and software costs substantially higher than those of a textbook-oriented curriculum, the continual user- costs of Internet-modem connections are substantial, and perhaps prohibitive. If they are prohibitive, at least within the public education sector, there is a danger that the impact of computers (and the Internet) on the school curriculum may split between those who pay for the full service, those who get a partial version of the service, at school, those who get a minimal service at school but privately supplement this to some extent at home, and those who get very little of the computer impact, at all.
References


MicroWorlds as a Learning Environment: Years 5 - 7: Tools Versus Thinking


Synopsis
This project is in proposal stage, with initial self-study and informal preparations underway since early 1995. It aims to investigate MicroWorlds (a recent hypermedia version of the educational computer programming language LogoWriter) as a support for learning across the curriculum, examining the tensions between learning computer programming, learning software skills, and use of "tools", "palettes" and "menu bar options".

Key questions include:
- What underlying mathematical learning is involved in developing computer skills within an interactive programming environment? this includes spatial thinking, logical processing, ordering and sequencing, numerical thinking, relationships, and scaling;
- What meta-learning, and meta-linguistic development occurs when students use an English-based computer programming language, as well an English-based technical language to talk about the work they are attempting; and
- To what extent does a menu-, tool- and palette-supported interface distract from problem solving thinking that might otherwise result from learning to program using a Logo-type language?

Introduction: Comparing LogoWriter and MicroWorlds
Here are some nuts-and-bolts comparisons between LogoWriter, as a programming world, and MicroWorlds as a hypermedia package.

Let me begin by comparing the different screen appearances of the two pieces of software. This will be a critical analysis of user-oriented on-screen interfaces.

[Note: When I resumed working in Primary Education in Victoria College in 1988, Dr Graham Ferres, then coordinator of the Graduate Diploma in Computer Education, asked me to prepare to teach LogoWriter in the next available semester, and said that this would also be something I could contribute to my undergraduate curriculum and methodology work. I had already had some experience with Logo, and was certainly interested. However this was my first real opportunity to put my interest into practice. The initial disasters that followed were entirely my own responsibility. But I lived to tell the tale, and it is very much due to Graham's initiative and support that, nine years later, I am continuing to engage in research in this area. In many ways, what I report here is collaborative work undertaken with Graham and our students. Indeed, I had hoped to be able to undertake the next stages of research in direct collaboration with Graham, as we had jointly developed the research proposal outline that led to this report. I mention all of this here, now, as partial repayment of years of gratitude owed to Graham.]
When Logo, in its earlier variants, was first loaded into a computer, all that was immediately visible was a "turtle", like a visual "cursor", awaiting instructions, possibly with a text-cursor silently flashing where instructions could be typed in "immediate mode". The screen made no attempt to explain itself, or explain what to do or what could be done. Everything had be developed out of the Logoer's head, referring always to a "dictionary" of Logo commands, and to cryptic key-stroke commands that could shift from visual-display ("Full screen") to text-display ("Edit mode") to mixed-display ("immediate mode").

With the advent of LogoWriter, the special metaphor of LogoWriter as a "book" attempted to bridge this what-can-I-do-next? barrier. The process of loading LogoWriter moved screen-by-screen from a "Title Page", to a "Contents Page" and then to a "New Page", or some other page which was either automatically provided, or had already been made in previous work sessions. In either Apple IIe or IBM versions of LogoWriter, a Title-bar was visible at the top of the screen (possibly with the cryptic sign of ??? if the New Page was so far un-named), with a turtle sitting in the middle of the screen, a screen-text cursor unmoving in the top-left of the screen below the Title-bar, and a lower section of the screen, known as the Command Centre, where the active text-cursor was flashing, awaiting orders. With "dictionary" or worksheets in hand, the Logoer proceeded, otherwise unaided.

By pressing the Apple (�) and the F key simultaneously (or on IBM the Control and F keys), it was possible to go to the other "side" of this screen or "page". On the Flipside there was no turtle (Edit mode), but it was possible to do serious programming. The programs were then run by flipping back to the front of the page, and typing command words in the Command Centre and pressing the Return key. In very short time, students happily understood this intuitively appealing metaphor, and programmed, and trialled, and flipped back to edit "procedures" (as programs were called), and so on. Typing and editing were easily handled by simple word processing techniques—hence the word "Writer" in the name "LogoWriter".

Things changed dramatically with the introduction of LogoWriter for Macintosh computers. Now there were the standard Macintosh-type Windows-style menu bar options at the top of the screen, scrolling bars at the right-hand side of the screen, and two small screen-buttons that could be clicked with the computer's mouse to "flip" or to stop any program that was running.

But much of this was just visually cosmetic. The keyboard-oriented features of Apple IIe LogoWriter were all retained in this Macintosh version. The windows-style pull-down menu options simply offered a different kind of access to ordinary features such as editing text, saving pages, and so on. The interface was more immediately attractive, but was essentially isomorphic to the first version of LogoWriter, itself a considerable advance on the very first interfaces for earlier Logo languages.

But MicroWorlds? Very very different. While major aspects of the LogoWriter interface were retained, there were some very significant additions. This is the nub of my concern, as a programming teacher, and the focus of my proposed research. Indeed MicroWorlds is essentially LogoWriter with a collection of hypermedia add-
ons, and some significant programming losses (including considerable complications in putting text onto the screen, and a loss in easy user-interaction, and an inability to use the mouse as a programmable object). In MicroWorlds the screen for a new page or project displays a fairly typical Macintosh-style menu bar, below this an upperscreen containing a turtle, and below that a Command Centre. But there is also a Tools palette... And therein lies the rub.

Let's pause to compare the menu bar pull-down options of LogoWriter and MicroWorlds.

**LogoWriter pull-down menus**

<table>
<thead>
<tr>
<th>Apple</th>
<th>File</th>
<th>Edit</th>
<th>Search</th>
<th>Font</th>
<th>Utilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Help Primitives</td>
<td>New Page</td>
<td>Undo</td>
<td>Search...</td>
<td>types</td>
<td>Gadgets</td>
</tr>
<tr>
<td>(an on-line dictionary)</td>
<td>Get Page</td>
<td>Cut</td>
<td>Replace...</td>
<td>sizes</td>
<td>Pics</td>
</tr>
<tr>
<td>Help Page</td>
<td>Name Page</td>
<td>Copy</td>
<td></td>
<td>Sound</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Save Page</td>
<td>Paste</td>
<td></td>
<td>Print Color</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Close</td>
<td>Clear</td>
<td></td>
<td>Print</td>
<td></td>
</tr>
<tr>
<td>Enlarged</td>
<td>Print Screen</td>
<td>Select All</td>
<td></td>
<td>Confirm</td>
<td></td>
</tr>
<tr>
<td>Saved</td>
<td>Print Text</td>
<td>Shapes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Page Setup</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MicroWorlds pull-down menus**

<table>
<thead>
<tr>
<th>File</th>
<th>Edit</th>
<th>Font</th>
<th>Pages</th>
<th>Gadgets</th>
<th>Help</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Project</td>
<td>Undo</td>
<td>fonts</td>
<td>New Page</td>
<td>Run</td>
<td>Vocabulary</td>
</tr>
<tr>
<td>Open Project</td>
<td>Cut</td>
<td>Name Page</td>
<td>Snaptext</td>
<td>Last message</td>
<td></td>
</tr>
<tr>
<td>Close Project</td>
<td>Copy</td>
<td>Style</td>
<td>Duplicate Page</td>
<td>Tool Palette</td>
<td>Ideas</td>
</tr>
<tr>
<td>Save Project</td>
<td>Paste</td>
<td>Color</td>
<td>Procedures</td>
<td>Tool Sounds</td>
<td>?</td>
</tr>
<tr>
<td>help&quot;</td>
<td>Clear</td>
<td></td>
<td></td>
<td>Command Centre</td>
<td></td>
</tr>
<tr>
<td>Save Project As</td>
<td>Find/Change</td>
<td></td>
<td></td>
<td>Record Sound</td>
<td></td>
</tr>
<tr>
<td>Page Setup</td>
<td>Cancel</td>
<td></td>
<td></td>
<td>Melody</td>
<td></td>
</tr>
<tr>
<td>Print Page</td>
<td>Stopall</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Print Project</td>
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<td></td>
</tr>
<tr>
<td>Quit</td>
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</table>

Immediately we can see in MicroWorlds that the interface metaphor of a "book" has been modified into some combination of "project" and "pages", whereas in LogoWriter the idea of "page" corresponded simply to typical software ideas of "document" or "file". We jump from a single idea to one which verges on needing organisational thinking to handle pieces of work and parts of pieces of work. This is "directory-think", not intuitive. Moreover, while a LogoWriter page has two sides, one with a turtle and one with programming, in MicroWorlds the equivalent to a single LogoWriter page is a project, which itself can have many pages with turtles, yet which has only one page for programming, known as the Procedures Page.

We can contrast this with HyperCard, a Macintosh-based hypermedia authoring software package which uses the organisational metaphor of Index cards and Stacks of such cards – similar, but arguably more intuitive than the less formalised idea of "project". Sadly, many of the significant changes MicroWorlds has overlaid on the underlying base of LogoWriter can be seen to be imitations of HyperCard which is a very powerful and appealing package, with excellent potential for programming. But usually the MicroWorlds imitations are cheap hand-me-downs, poor relations, or
decidedly pale. And while LogoWriter is immediately accessible as a programming language for school students as young as Grades 2 or 3, HyperCard is decidedly challenging for students at lower Secondary level, and MicroWorlds is comparably challenging – another major grievance of mine about MicroWorlds.

What do we get in terms of hypermedia with MicroWorlds which is not available in LogoWriter? Consider the palettes of tools.

**MicroWorlds Tool Palette**

<table>
<thead>
<tr>
<th>Command Centre access</th>
<th>Shapes Centre</th>
<th>Drawing Centre</th>
<th>Procedure Page access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turtle Tool</td>
<td>Textbox Tool</td>
<td>Button Tool</td>
<td>Slider Tool</td>
</tr>
</tbody>
</table>

Clicking on one of these tools gives a different display, revealing the Command Centre, or a collection of Turtle Shapes with other tools for drawing and working with these shapes, a Drawing Centre of Graphics palette of tools (including an arrow pointer, select-box, tools for drawing lines, rectangles, filled rectangles, ovals, filled ovals, erasing, a paintpot and a spraycan, and so on), and other tools for creating special screen objects such as buttons (that can be clicked with a mouse to run specially created programs), textboxes (that can display text), and sliders (that work like stereo-controls to adjust the values of specified variables). Under the menu bar pull-down option of Gadgets we can also access a Melody tool palette that lets use create and name a tune (one note at a time), by clicking with the mouse on a duration-palette (where we can select quaver, crotchet and minim) and an instrument palette (violin, clarinet, mandolin and orchestra), and then click on keys of a piano keyboard.

So much to choose from, so much to do, so little time to do it in. Such fascinating distractions! Ah, me! Pity the children faced with such potential bewilderment!

Perhaps more specifically, we can consider the way MicroWorlds' Drawing Centre can create an interesting pattern, compared with the corresponding program which LogoWriter requires to obtain the same effect. Incidentally, can you tell which of the following diagrams was created using MicroWorlds' Drawing Centre and which was made with a LogoWriter procedure?

Using MicroWorlds' Drawing Centre we need to point-and-click with the mouse on the Rectangle tool, then click at the desired starting point on the screen, and while still holding the mouse-button down we drag to open up the desired rectangle; and we repeat this four times. With LogoWriter we create a procedure, called `box` naturally enough, which will draw a box, and then we use `box` as a new command word in another procedure called `box.turn` which does, four times, a drawing of a box, a small move forward, and a right turn of 90 degrees.
Of course, we can make exactly the same program in MicroWorlds using its built-in equivalent of LogoWriter-the-language. The research question is whether or not school children would be willing to work to learn how to use the language, when they could just point and click a few times and get the same result? Does MicroWorlds offer too much, too easily, too attractively?

Similarly we can consider putting shapes on the page using the Shapes Centre and point-and-click mouse actions:
• click on the turtle and drag it to the desired location,
• click on the desired shape in the Shapes palette,
• click on the turtle to assign it this selected shape,
• click on the Stamp tool,
• click on the turtle to stamp the currently selected shape in the currently selected position,
• repeat these five steps as desired.

Compare this with the corresponding approach using programming, which emphasises the coordinate location of the turtle's position, using _setpos_, and the assignment of a specified shape using _setsh_, and so on. Note the explicit use of mathematical coordinates!

```plaintext
to do.Stamp
  pu setpos [-100 50]
  pd setsh 12 stamp
end

or

to do.Any.Stamp :n :x :y
  pu setpos list :x :y
  pd setsh :n stamp
end
```

We can say exactly the same kinds of things about MicroWorlds' Melody palette, except that in this case there is nothing tangible to show for all the pointing and clicking, except a named sound resource. For example we can point and click and create a melody based on the first notes of Beethoven's Fifth Symphony, and when we type _run "beethoven"_ we can hear this. We can even go back, through the melody palette, and edit this if we like. But I do not believe this compares with the thoughtful learning involved in creating the following procedure on a MicroWorlds Procedure page (equivalent to a LogoWriter Flipside, although LogoWriter has a slightly different, more Physics-realistic approach to creating notes using a command _tone_ based on the frequency of each note.). (Nor does it compare with HyperCard where similar automated devices create sound resources with no need for the user to directly
program anything, but the devices do also provide a small editable program to handle the sound resource so created.)

to beethoven.5
note 64 2
note 64 2
note 64 2
note 60 4
repeat 3 [note 62 2]
note 59 4
end

But what is Logo for?

LogoWriter, and MicroWorlds also, are part of a large family of Logo languages which owe their existence to the educational vision of Seymour Papert. In his book *Mindstorms* (1980) Papert describes his childhood memory of playing with gears and cogs, and the mental models they provided him at key points in learning school mathematics. 'I became adept at turning wheels in my head and at making chains of cause and effect ... Gears, serving as models, carried many otherwise abstract ideas into my head ... I saw multiplication tables as gears, and my first brush with equations in two variables (e.g. $3x + 4y = 10$) immediately invoked the differential' (p. vi).

Papert goes on, linking personal experiences with gears, school mathematics, affective learning and Piaget's theory of cognitive development: 'A modern-day [Maria] Montessori might propose, if convinced by my story, to create a gear set for children ... But to hope for this would be to miss the essence of the story ... Something very personal happened, and one cannot assume that it would be repeated for other children in exactly the same form' (p. viii). Papert's project or thesis then was this: 'What the gears cannot do the computer might' (p. viii). The result was Logo.

Logo dialects generally, and especially LogoWriter, do achieve what Papert hoped for. The computer – that is, the experience of programming through a carefully designed learning-potent language – does carry otherwise abstract ideas into students' heads. LogoWriter provides a 'Mathland' we can travel in, which, as Papert suggests, corresponds for the learning of mathematics to the way that travelling to France is the best way to learn to speak French (Papert 1980, p. 6).

In what way is doing LogoWriter programming a form of doing mathematics? It certainly embodies many basic mathematical features, such as coordinates, distance, angle, bearings, and so on. But the real proof of this comes from reflecting on the experience of starting to learn and use LogoWriter. Although we may not be conscious of doing so, we will be using many problem solving strategies as we try to work out what each primitive command means, what each one will do in this particular case, and what successive commands will do as each one runs after the other. When our programming goes wrong, again we will be using problem solving skills to try to identify and fix ('de-bug') the fault. We will think things like: I think it goes wrong here, so if I change it this way then it should work, and you will then perform a small-scale mathematics experiment as you attempt this correction.

At the end of making a procedure we will have succeeded in creating a kind of total statement, using primitive commands (and possibly other names of other procedures
already made), which results in a certain collection of actions on the screen. This closely resembles the making of a mathematical argument, based on certain initial assumptions (and possibly other arguments already completed), which results in demonstrating that a certain mathematical statement is correct. Mathematicians speak of "proving" something. Each LogoWriter procedure is like a mathematical 'proof' of what the procedure does, but apart from its formal rigour this "proof" is always intuitively sensible. Indeed it was precisely for this mathematical potency that Seymour Papert first developed Logo.

What now is at stake is whether or not MicroWorlds offers the same possibility. I have my doubts – not that I am entirely prejudging the question – and hope to be able to investigate this.

**Research Issues in ICT and Logo and other educational programming**

- different kinds of software - "book", "game", "obvious toolkit", obvious process, not so obvious thinking
- different interfaces: Logo, LogoWriter (Apple IIe), LogoWriter (Macintosh), MicroWorlds (Macintosh, IBM)
- what is Logo about? what did Papert intend for it? how is it used?
- "immediate mode" versus procedures and programming
- programming is mathematics

**Research Possibilities**

- observation of students in class
- school teacher survey and interview with questionnaire
- survey of relevant literature in conference proceedings and journals
- individual case studies of student learning
- anecdotal notes from my own teaching with LogoWriter and MicroWorlds
- contact with interest-groups and user-groups through the Internet
- contact with the software developers and publishers
- responses to published articles on the issue
- survey of sales of LogoWriter versus MicroWorlds

**References**


Notes on Research and Advice for Students in Deakin Education Masters Degrees

Yet again I have become the supervisor for a Masters student doing (in this case) EXE740 Independent Reading Study (but the same issues arise with supervising students in EXR790 Research Design and Development), and found myself asking the student:

— what are you doing this unit for?
— are you considering doing a later research unit (e.g. EXR792 or EXER794)?
— what other units have you already done that properly relate to any later research units (such as EXE780 Research Perspectives and Practices, or EXR790 Research Design and Development)?
— what do you know about applying for Ethics approval to conduct research?
… and so on

Yet again I have typed ad hoc informal notes for the individual explaining how the research-linked units are meant to link.

The student later thanked me, and said no one had explained these matters before.

I occasionally discuss these issues with other staff (in impromptu corridor meetings), and the same issues were discussed earlier this year (2004) in relation to EXR792 Research Paper and the requirements of the Ethics committee.

I know that with hundreds of Masters students it is impossible for any one person to give detailed individual course advice to all students. But I am not convinced that essential advice is provided in the Post-Graduate Handbook, nor in currently used unit materials.

Typically, it is not until a student is paired with a unit-supervisor for EXE740 Independent Reading Study, or EXR790 Research Design and Development, or EXR792 Research Paper, that the student finds out how other units can link with possible research within the Masters.

This means that each of us, when we begin individual supervision, start drafting and delivering the same general messages.

The move to provide a How-to-Apply-For-Ethics-Approval booklet with the posted materials for EXR792 is excellent! (I commend Ian Robottom, and Geoff White, and Peter Smith, and others for their work in developing this booklet).

But the advice about Ethics is only part of what is needed. And the advice, within the Unit Guide for EXR792, comes rather late for students who have not yet begun personal supervision with a research-guiding lecturer.
In the interests of clarifying and fixing what is clearly a problem, let me suggest that some version of the following be turned into a flier, that ALL Masters students will routinely receive with their bundled materials for all units.

I would be interested in any comments.

If anyone wants to use any part of my pasted discussion below, edited in any way, please feel free to do so.

John Gough

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Pathways Towards Your Own Research-work in a Deakin Master of Education Degree By Coursework

INTRODUCTION: Starting a Masters Degree by Coursework — Do You Want Research With That?

You are enrolling in a Deakin Masters degree with the faculty of Education. Your degree will be by coursework. The degree is worth EIGHT points of study. Typically most units at Masters-level are each worth 1 point. Hence a coursework Masters degree could consist of a maximum of EIGHT units.

These eight units may, within the official constraints of the Post-Graduate Handbook, be freely chosen by students, like a smorgasbord. A little of this, a bit of that, and a spot of something else. As with any “smorgasbord”, it is possible that the eight units may have no direct relationship with one another. Instead each one would simply represent one of many unconnected interests a student may have.

Against this free-choice “smorgasbord” it must be noted that, as the Post-Graduate Handbook explains, some of the Masters degrees have a special “appellation” or “labelling”, such as “Arts Education” or “Curriculum Studies”. Each appellation prescribes certain limits on which units a student may enrol in, thus restricting the available smorgasbord menu choices for a student.

Leaving these appellation constraints aside, it is possible to complete all eight points WITH NO OVERT RESEARCH COMPONENT OR WORK AT ALL, apart from the sense of “research” meaning wide reading, critical analysis and reflection, and formal academic writing and related activities that are part of Masters-level study.

Here, by “research”, I mean gathering information about a specific topic or question about which there is some uncertainty, or controversy within the world-wide educational community, with the aim of finding out more about the topic or question, so that the world-wide community might be better informed about the nature of the topic or question (if the person doing the research were later able to publish some version of the results of the research). By “researcher”, here, think of “experimental scientist”, “interviewer”, or “investigator”, and contrast this with “student” or “learner”. Typically, students learn by research-like processes. But what they learn
contributes (mainly) to their own personal knowledge of a particular topic. It does not contribute to what the world, at large, knows about a particular topic. By contrast, research, rather than study, does (potentially) contribute to what is known about the topic.

Let us suppose, however, that you have in mind using your Masters degree to do more than just enrol in and study, as a student, eight (possibly isolated, or unconnected) smorgasbord units of coursework. Instead you expect, or plan, at some time in your degree, to complete your Masters with some form of educational research of your own.

This can take at least four forms, some more overt than others.

1. **Research within a unit’s ordinary assignment(s)**
   In several units the assignments provide small-scale opportunity to conduct research, which will be reported on in the form of an assignment or assignments, submitted for that unit.

   For example, in EXE733 Assessing Learning, the open-ended possibilities for the two prescribed assignments give a student scope for negotiating with the unit-chair to read published materials on a particular topic related to the unit’s broad concern for “assessing learning”, and perhaps survey workplace colleagues about their current assessment policies, methods, or interview them about their attitudes to assessment. Alternatively a student may use the demands of the unit’s assignment(s) to develop and trial a new assessment method, or to make an extended critical analysis of some assessment method that the student is currently using.

   Similar research-related possibilities arise naturally, independently, in many of the other units at Masters-level. Such research, forming a natural part of the study and assignment work of these units does NOT require any special ethical approval, although students will be expected to conduct their research in ethically sound ways.

   Similarly, this kind of small-scale assignment-like research will be negotiated with, and supervised by the unit-chair of the individual unit, or by another staff-member also teaching or involved with this unit.

2. **Research within EXE740 Independent Reading Study**
   As the Post-Graduate Handbook entry for this unit explains, a student enrolled in this unit reads widely on a topic of the student’s choice. While reading, and towards the end of the unit, the student drafts and then submits a single large assignment as fulfilment of the assessment requirements of the unit.

   This assignment is essentially a major Literature Review and critical analysis (critique) of existing published research on the selected topic.

   The student’s reading and drafting is personally supervised by a member of Faculty staff who not only has some expertise and interest in the student’s topic, but also marks the final assignment.
3. Research within EXE790 Research Design and Development

At the risk of duplicating the Post-Graduate Handbook entry for this unit, the study and assessment demands of this unit may be summarised as follows. By the end of the unit the student will have:

- read widely on a specific topic, selected by the student, with supervision and negotiation with a member of Faculty staff (as with EXE740);
- drafted (i.e. proposed) a clear research question, related to the selected topic, and possible sub-questions;
- devised a suitable method (methodology) for conducting research that could gather data that would help investigate, and potentially provide answers for the proposed research question;
- drafted an Ethics Application, which may later be used to apply for approval from the Faculty of Education’s Ethics sub-committee: this draft Ethics Application itself contains:
  - a draft Research Proposal
  - a draft research question (and possible sub-questions)
  - a brief outline of the background to, and justification for mounting the research (or its proposal)
  - a draft Plain Language Statement (or several statements), explaining the research proposal in simple English that will be understandable by those people who may (later) be invited to participate in the proposed research, and may provide data that would be used to investigate and perhaps develop answers for the proposed research question (such possible invited people could include, for example, other teachers, school students, and, in the case of under-age minors, the parents or guardians of under-age school students — hence the need for “plainness” and clarity in the Plain Language Statement.

Note that normally a student enrolling in this unit will already have completed the unit EXR780 Research Perspectives and Practices, as well as at last 2 other units of Education Faculty course-work.

Note also that the “R” in the letter codes for these units — EXR — denotes the “research” component or focus of each unit.

In this unit the student’s study, generally, that is, reading and drafting, is personally supervised by a member of Faculty staff who has some expertise and interest in the student’s topic. The staff member also marks the final assignment.

4. Research within EXR792 Research Paper (a 2-point unit), or EXR794 Minor Thesis (a 4-point unit — equivalent to half of a complete 8-point Masters degree)

The names of these two units clearly shows that they entail research. Importantly, however, bot units have pre-requisites. Any student enrolling in either of these units must already have completed BOTH of (or an alternative to):
EXR780 Research Perspectives and Practices and
EXE790 Research Design and Development.

Again, as with EXE740 and EXR790, students enrolling in either of these units will work under the supervision of a member of Faculty staff who has some expertise and interest in the student’s topic.

But in the case of EXE792 and EXE794, the individual supervisor will NOT mark the final assignment, the Research Paper or the Minor Thesis, but will select a suitable examiner (for EXR792) or two suitable examiners (for EXR794).

Note that students may enrol in EXE740 Independent Reading Study without serious demand for pre-requisite, except that the unit is generally intended for students who have:

- already studied as far as they can in a particular topic of interest, by means of a unit (or units) that, in some way, may focus on this topic; or
- some alternative topic of interest which is not otherwise catered for in any other existing unit available at Masters-level.

Similarly the unit EXR780 may be undertaken at any point in the student’s Masters degree, without pre-requisites.

However, the units EXR790, and EXR792 and EXR794 all require research-focused pre-requisites. But, importantly, students enrolling in EXR790, EXR792 or EXR794 need not have completed EXE740 Independent Reading Study — the “Literature Review” unit. Despite this, both EXR792 and EXR794 will expect a student to include a Literature Review as a major “chapter” in the final Research Paper or Minor Thesis. Moreover, the development of a research proposal, and Ethics application, in EXR790, also requires considerable background in the proposed topic for research, as well as some rationale for the proposed research, and some argument for the use of proposed research method(s).

This opens the following discussion of unit sequencing, from start of a Masters degree by coursework to some eventual extended research.

**Planning Ahead for Overt Research Within a Coursework Masters**

If any student plans to enrol in the unit EXR792 Research Paper, or the unit EXR794 Minor Thesis, at some future time, this needs careful thought.

The beginning of this must be, at some stage in the whole Masters sequence, EXR780 Research Perspectives and Practices.

The unit EXR780 explores possible methods of approaching research, as a subject for study in its own right, and alternative methods for doing research. This unit gives the student choices of “research-tools”, along with the underlying methodological theory and rationale(s) for choice of research method(s), which are needed, later, for developing any research proposal (as in the similarly preparatory unit EXR790, or in the actual units of active researching, namely, EXR792 and EXR794).
Next, consider the unit EXE740 Independent Reading Study. As already noted, it is possible for this unit to be a stand-alone unit, within the larger smorgasbord-like scheme of the eight units of a coursework-based Masters degree.

But very importantly, many students use EXE740 as the time when they establish a strong Literature Review for their later Research Paper or Minor Thesis.

If students complete EXE740 well they have established a strong draft of their Chapter 2: Literature Review (and maybe Chapter 3: A Critical Rationale for the Proposed Research, that will later emerge in their Research Paper, or Minor Thesis. Also, in conjunction with a well developed Literature Review, itself, the wide reading that occurs in EXE740 will also expose students to a wide-range of research methods, thus extending and focusing the general methodological background (already? or later?) explored in EXE780. Hence, aspects of EXE740 can combine with experiences arising in EXE780, to help students develop their research methodology (methods), which becomes Chapter 4: A Methodology for the Proposed Research.

But this is only possible if students plan ahead for their enrolment in successive Masters units.

Before a student undertakes the EXR792 Research Paper, if the student is intending that the proposed research would require gathering data (measurements, test results, questionnaire information, interview transcripts, classroom observations, etc.) from human research subjects (or participants), the student needs to develop an Application for ETHICS Approval that would be submitted to the Education Faculty Ethics sub-committee.

As already noted, a central, and absolutely essential component in any draft Ethics application is a PLAIN LANGUAGE STATEMENT (PLS) which outlines in simple English as clearly as possible what the research is going to be – expressed in language that can be understood by the people who will be agreeing to participate in the proposed research, and hence who will be providing data for that research.

The student also needs to develop a draft research project proposal. A central, and absolutely essential component in any draft research proposal is a RESEARCH QUESTION.

Many students complete these two parallel tasks (the Ethics application and the Research proposal) as “assignments” while enrolled in the preparatory unit EXR790, which is itself a sequel unit to EXR780 which exposes students to varieties of research methodologies.

Hence by the time the student enrols in EXR792, there are draft versions of major components of the actual Research Paper, and all that needs to be done is to:
- DO the research (gather the data),
- collate, summarise, and analyse the data and the results of the research
- draft a final report on what the research found, or in what ways the research was able to answer the major research question.
When the student begins EXR792 the student will (often) already have completed draft versions of:

- the research question (in EXE790)
- the Ethics application and Plain Language Statement (also in EXE790) and
- the Literature Review (in EXE740).

In essence, seen within this larger context of any version of a Deakin Masters degree which culminates in a Research Paper, or a Minor Thesis, any version of EXE740 Independent Reading Survey will not be independent, supervised reading, on a negotiated topic, undertaken for reasons of personal interest, or for the sake of doing something academic, and earning one credit point towards the whole Masters degree. Instead it will be a critically gathered and analysed Literature Review which provides a critically argued case for mounting the research which is to be proposed, separately, in EXR790, and undertaken, separately, in EXR792.

**Where Do Supervising Staff Members Come From?**

Typically students who approach the eventual EXR792 Research Paper in this coordinated way will also move from the very first research-methodology-focused unit, EXR780, through other units, with a germinating idea for research already in their mind, and also, CRUCIALLY, with an idea of WHO they would like to be their supervising staff member through EXR790 and later in EXR792.

It is possible to have different staff members supervising each unit. But many students find it helpful to follow through the sequence of units I have been outlining with the same supervising lecturer through them all. Frequently this lecturer is one who has already revealed some interest in the student’s general area of interest for possible research. Usually this happens through the lecturer’s teaching of some other coursework unit(s), where the topic(s) of the unit(s) is(are) related in some way to the student’s topic(s) of interest.

For example, a student who is interested in, and considering research theories of learning, and classroom applications, may encounter a lecturer working in EXE736 Knowledge, Learning and Learners. Another student considering research in literacy may encounter a lecturer teaching a unit such as ECL767 Reader and Text or ECL756 Text Analysis for Language Teaching.

**Can You Plan Ahead, Now, For Possible Research?**

Having explained all of this, where do you stand, in this larger sequence of units, EXR780, EXR790, and EXE740, and beyond — EXR792 or EXR794?

— Have you enrolled yet in EXR780 Research Perspectives and Practices?

— Have you enrolled yet in EXE790 Research Design and Development?

— Do you have any early idea(s) about what research you might attempt in EXR792?
— Have you already encountered any indicative (interesting, challenging, inspirational, or guiding) research materials, journal articles, or other early appetite-whetters?

— Have you any experience of, or knowledge of possible methods of research?

— Have you some (tentative) reason for wanting to conduct research, and/or some (tentative) rationale for proposing some research?

— Do you have a draft research question, or a draft Plain Language Statement?

— Have you considered issues of ethics in any possible research? For example, could your research pose any dangers or threats to possible research participants — the people who you would want to get information from, to help investigate an answer possible research questions?

For example, regarding issues of ethics in educational research, if you are the teacher of Year 8 Geography students, and you want to research Year students’ ability to read technical maps, and you are considering using your own Year 8 students as the subjects of your research, there is an immediate danger for your students. This danger is an ethics issue or problem!

If the students agree to participate in your research, is this likely, in some way, to positively color your teaching of them, and your assessment of their schoolwork in Year 8 Geography?

Or, if they decline your invitation to become research participants, might this negatively color whatever you will continue to do with these students in your non-research role as their Year 8 Geography teacher?

If your research involves implementing some innovative curriculum materials, will students who are NOT part of your research suffer any adverse consequences from NOT experiencing these curriculum (or pedagogical) innovations?

Similarly, if implementing such an innovation means that the research participants will NOT receive the otherwise standard or traditional presentation of the curriculum topic being taught differently through this innovation, will this gap in, or modification of their experience adversely affect their overall learning of this curriculum topic?

— Are there potential conflicts of interest, between your role in your workplace, and the roles and positions of those possible research participants?

For example, if you are the curriculum coordinator for a school, or the deputy principal, how will other teachers feel about being invited to become research participants, knowing that how they respond to the invitation may be, directly, or indirectly, related to other judgments you may make about their professional standing, performance, and possible promotion?

Ethical issues (conflicts of interest, conflicts in professional expectation and performance) need to be anticipated, and managed, in clear and practical ways. The
goal is openness, and fair dealing, and to minimise and, if possible, avoid any harm to both those potential research participants who accept your invitation to be part of the research, as well as those you invite who choose to decline the invitation.

**Summary: Placing Preparatory Units Within a Research Paper or Minor Thesis**

A short way of seeing these issues is this: a Research Paper or Minor Thesis may, typically have a **Contents-listing of chapters**, such as:

- **Abstract**: an extremely brief encapsulated or nut-shell account of the research: what it proposed, and attempted, and found, possibly with a brief statement about how the research was conducted.

- **Chapter 1: Introducing the Topic of the Research**
  1.1 The Research Question
  1.2 The Rationale for the Research

- **Chapter 2: Critical Literature Review: The Background to the Research** [based closely on EXE740 Independent Reading Survey]
  2.1, 2.2, etc. — these sub-sections make sensible subject-compartments dealing with discrete sub-section aspects of the research and related background issues

- **Chapter 3: A Critical Rationale for the Proposed Research** [based on Chapter 2, plus aspects of the Ethics application, developed in EXE790 Research Design and Development]:
  a critically argued case for conducting the proposed research in a specific way: for example, by Case Study, or by Participant Observer, or whatever research method(s) are argued to be most suitable for the researcher, the context and the research question.

  (As noted, this may develop directly from the unit on Research Methodology, EXR780, along with other wider reading, such as through Chapter 2, where the research methods of other published research have been examined critically.)

- **Chapter 4: A Methodology for the Proposed Research** [derived from EXE740, and, essentially, EXR780 Research Perspectives and Practices], including Ethics issues:
  4.1 Who was recruited as research participants, and how
  4.2 An account of the handling of ethical issues arising during the research process
  4.3 A description of the data-gathering methods used

- **Chapter 5: An Outline of the Implementation of the Research** [this is a report on the main researching conducted during either EXR792 Research Paper, or EXR794 Minor Thesis]
• Chapter 6: Results of the Research [again, this is a major aspect of either
EXR792 or EXR794]: a Summary of what was found (answers to the research
question) from the research data

• Chapter 7: Discussion of Results and/or Conclusions: a critically analysed
discussion of the major findings of the research
  6.1, 6.2, etc., sub-section by this chapter outlines successive findings
  6.4? A statement about the limitations of the research, as it was conducted (e.g.
the smallness of the sample of participants, the lack of precision in some
qualitative data, the fact that the research examined only teachers or teaching in
one small part of one State, in an English-speaking country, and/or the fact that
special issues [e.g. gender, indigenous or immigrant peoples, socio-economic, class
or whatever] could not be addressed in the practicable research sample]

  6.5? The need for further research, and possible areas of such further research,
and/or fresh research questions now arising from the completed research, ...

If you are likely to reach the end of your coursework Masters degree with such a
Contents-listing for an extended piece of research, you need to understand how the
preparatory units build towards the earlier chapters, while the culminating research
unit puts all the preparation into practice, and is then described, analysed, and
critically summarised in the final chapters.

Do You Want a DOCTORATE With That?
So far I have discussed research possibilities within a Deakin University Masters-
level degree in the Education Faculty. But some students entering a Masters degree,
or currently in a Masters, also hope to move eventually from a completed Masters
degree to a doctorate of some kind.

There are essentially TWO kinds of doctorate:
— a course-work-like EdD, or Doctorate in Education; and
— a more research-emphatic PhD, or Doctor of Philosophy (so called — this is the
technical term for a research doctorate).

Why would any one subject themselves to the many years (usually a minimum of 3
years full-time) of extremely demanding academic work and research?

There are two main reasons, other than that of personal interest, and growth:
• wanting to become a university lecturer; or
• intending to do research.
Importantly, if you want to pursue a career as a university lecturer it is essential to have a PhD so that you can yourself supervise doctoral students. I doubt that anyone in Australia (or elsewhere) would be appointed, these days, to a lecturing position without already having a doctorate, or being within, perhaps, one year of completing a doctorate.

It is important to note that the entry requirements to a doctorate (at Deakin) are:
- a Bachelor-level Honours degree with an overall result of H2A (whatever that means, when translated from one Faculty, or one university, to another); or, equivalently
- a (Deakin, or equivalent) Masters in Education, which includes results of DISTINCTION or better in the three research-focused unit (totalling 4-credit points in the whole degree): EXR780, EXR790 and EXR792; and, if possible as many DISTINCTION grades in the other units in the Masters degree.

Students who have not received grades of DISTINCTION for all three of these units have been excluded from enrolling in doctoral studies (although it is then possible for them to pursue further Masters study, possibly elsewhere, in the hope of earning suitably high grades in equivalent units to compensate for the sub-Distinction grades in the Deakin units).

Similarly, if anyone is interested in undertaking research, with or without being a university lecturer, this seems to be possible in only three ways, other than a do-it-yourself back-yard home-office amateurism. These are as:
- a hired researcher, working for a corporation, education authority, or similar organization;
- a successful competitor who has submitted a detailed research proposal (as a tendering process) to a research funding authority, such as a national government, or agency; or
- a university academic undertaking unfunded, or university-funded research (in this latter case, after successfully tendering for university research funds).

In all three cases, it is extremely unlikely that anyone could be a successful tenderer, or be in a suitable position to be allowed, and be funded, to conduct research, UNLESS that person already had a track-record as a researcher.

The usual first step in such a track-record is at least having a completed research-based doctorate, and probably also having several published articles, or monographs, or conference presentations, based on the person’s research (such publication needs to be “refereed”, that is, in prestigious, editorially screened professional journals).

By contrast, if such a person has, at most, only the research conducted within a Masters degree, even where that research essentially constitutes the entire degree (which is possible, at Deakin, as Masters-by-research, where all 8 credit points of the degree constitute the research and full or “major” thesis), this does NOT constitute that necessary first step, unless, almost accidentally, the quality of the research, or the topic of the research is for some extreme reason so substantial that it warrants comparison with a doctorate.
Ordinarily a good Masters research-supervisor would advise any Masters student that if the Masters-level research, while underway, seems of sufficient quality, the student should upgrade the enrolment from Masters to doctorate.

Very rarely would a student complete any Masters research that anyone else would accept as being of doctoral scope or quality.
Appendices
The following Appendices include materials used, and potentially useable, to collect research data for further analysis.
Computers, Writing, Thinking — Self-Inventory — November 1999

Most adults and teenagers learned to write using a pencil or pen, and learned to read using paper-printed materials. A few learned to read independently of almost any overt instruction, especially now that see-and-hear TV ads make frequent dynamic links between spoken and written/printed language. But since 1995, when Microsoft introduced Windows 95, and IBM personal computers went ‘windows’, with point-and-click easiness, increasing numbers of young students’ initial experience of reading occurs with a computer screen, and ‘writing’ is a mix of mouse-actions and key-strokes. Moreover, many pre-school practice game programs ‘speak’ back what the user types! The times they are a changin’. What you knew, and experienced, may soon be very different from school and the curriculum of the future.

The following questions relate to the use you make of computers, and your views on ‘writing’ (by hand, and/or wordprocessing). Some of them may not fit your situation. Please answer as well as possible. If necessary add comments or explanations in the margin. You may feel it necessary to choose more than one of the alternatives to a particular question.

1. Which of the following describes your access to computers:
   A I have a personal laptop which I use at home, school and study
   B I have a desktop computer at home which I use as much as I need
   C I use a desktop computer at home which I share with other users
   D I beg or borrow computer time on a friend’s/school’s/library’s computer
   E I use only, or mainly, the university computer laboratories
   F I have someone else type up any work I need wordprocessed

2. If you have a computer which you are able to use a lot, please name it, as well as you can, and if possible indicate when you bought it, or how old it is

3. Presumably you were able to write reasonably well, by hand, before you developed any skill with wordprocessing. Which of the following describes your view of yourself as a pen-writer (ignore any limitations over spelling, grammar, or handwriting): that is, how well do you feel you can express your ideas when you write them out using pen and paper?  
   A I pen-write confidently
   B I pen-write competently, but am not always confident about being clear
   C I manage, but slowly and with difficulty and struggle to clarify what I think
   D I feel pen-writing is not a good way for me to communicate my ideas

4. When you pen-write a new piece of work (e.g. a university essay), which of the following describes your approach (or the approach you used to use):
   A I make many rough notes and then re-write several times before it’s right
   B I make a few notes and write one rough draft, then make a fair copy
   C I make a few notes, and when drafting use lots of white-out, and physical copying and pasting of pieces of draft, to assemble the ideas I want to express
   D I make a few notes, then usually manage to make one fair draft on the first attempt, which I submit, after simple proof-reading and minor corrections
E I work out what I want to say, in my head, then write it out, through successive drafts, until it’s right
F I work out what I want to say, in my head, then make one fair draft on the first attempt, which I submit, after simple proof-reading and minor corrections

5. Once you had learned the basics of writing by hand, you may have experienced a transitional stage of using a typewriter (not a wordprocessor) before moving to wordprocessing (indeed, you may still be just typing). Which of the following describes your experience (if any) with a typewriter:
A I type slowly, with frequent errors, lots of white-out, and re-typing
B I type reasonably fast, but need to draft first by hand
C I type my first and only draft directly on the typewriter, with some later small scale corrections, using only a few hand-jotted notes
D I can think and compose on a typewriter about as fast as I can hand-write as I express new ideas

6. Presumably you now use wordprocessing for all / almost your formal ‘written work’. Which of the following describes your approach to WP:
A I WP only at the last stage after the hand-drafted version is as good as I can get it
B I make extensive hand-drafted jotting-notes, and make a first hand-draft, before I start WP the essay
C I make extensive hand-drafted jotting-notes, and then WP all subsequent drafting
D I make a few hand-drafted jotting-notes, and then WP all subsequent drafting
E I make a few mental notes, and think a bit, then start WP
F I start jotting ideas directly on the computer, and do WP drafting all the way

7. Consider your different experiences of hand-drafting and wordprocessing. Which of the following describes your views:
A I express myself more easily using hand-drafting than WP
   If so, why? E.g. lack of computer access &/or time, weak typing skills, negative attitude to computers, preference for direct hands-on crafting

B I express myself more easily using WP than hand-drafting
   If so, why?

C WP has obvious technical advantages in being able to correct, cut, copy, shift, and check, but apart from that I feel I can hand-draft as well as I can WP

8. Which of the following describes your experience:
A I learned to touch-type to a comfortable speed
B I can only hunt-and-peck slowly when I type or use a keyboard
C I am a fast-enough two-finger typist
D I can type (somehow) about as fast as I need to keep up with my flow of ideas
E my handwriting is clear and easy to read even at speed
F my handwriting is OK when it’s slow but is hard to read when I have to go fast

9. Do you feel wordprocessing significantly changes your confidence and ability in expressing yourself in writing? YES / NO
Any comment about this?.............
10. What advice would you now give teachers or parents about wordprocessing versus hand-writing?

.............

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Now, draft your own set of questions about the following.

• Using e-mail for personal communication, contrasted with hand-written or typed paper-based letters, telephone conversations, and, possibly, faxes.

• Using the Internet as an information resource, contrasted with using a shelf of encyclopedias and reference books, or a good municipal library.

• Using a hand-held calculator to do everyday arithmetic computations, contrasted with pencil-and-paper written computations.
“Disaster Studies” and Other Learning Bugaboos from Robert B. Davis’s 

In the late 1990s, Science Education moved from its early embracing of a version of 
constructivism, as its explanatory theory (or metaphor) of learning, to exploration of 
what is sometimes called Alternative Conceptions, or Conceptual Change. The central 
argument was that, because Science was a conceptualising of real-world physical 
phenomena, the classroom challenge to form so called scientific concepts was always 
jeopardised by the fact that school students, and even pre-school children, had already 
created PRE-scientific concepts to explain their own, informal everyday experiences 
of the real-world and its diverse phenomena. Moreover, this real-world is dominated, 
for example, by FRICITION. That is, unless an object is being pushed by a force, the 
object will not move. If an object is observed to be moving, it must be due to the 
effect of some force being applied to the object. In short, before school students are 
taught Newtonian physics (where Newton’s First Law of Motion — or Law of Inertia 
— states that an object in a state of rest or continuous motion will continue in that 
state, unless a force is applied to change its speed or its direction), students are natural 
Aristotelians. Moreover, until Newtonian concepts are thoroughly internalised, 
students will persist to fall back on Aristotelian ideas of physics.

When university Physics students are presented with a novel situation, they are likely 
to forget Newton’s physics and give answers to questions according to Aristotle’s 
(friction-based) theories of motion. In terms of effective teaching and learning of 
Newtonian physics this is, conceptually, a “disaster”. However, in those late 1990s, 
few of the Science educators who were concerned with Conceptual Change and the 
resistance of informal non-scientific concepts to science instruction realised that 
“disasters” had been studied extensively in the late 1970s and had been compellingly 
discussed by one of the pioneering constructivist theorists, Robert B. Davis.

The following three examples, from Davis’s discussion, can be taken as a challenge to 
the reader: how do YOU answer these questions?

**1. Andrea A. Di Sessa’s “Dynaturtle”**

Imagine a rocket-powered space-ship. This can be modelled in Logo programming as 
a moving blip on a computer screen. It starts in the bottom-left corner of the screen. 
It is pointed vertically up the screen, in the direction of the y-axis of implicit 
Cartesian coordinates. The aim is for the student to steer the rocket to the top-right 
corner of the computer screen. The student can press three keys on the computer 
keyboard:

- **K** — fires the rocket, and adds a vector increment to the space-ship’s velocity; the 
  increment is directed in the same direction as the space-ship’s current 
  orientation
- **R** — causes the rocket to rotate 30 degrees to the right (clockwise) from its current 
  heading
- **L** — causes the rocket to rotate 30 degrees to the left (widdershins) from its current 
  heading

If the rocket has not been fired (K has not been pressed), then pressing R or L will 
rotate the rocket on the spot but not otherwise move it.

Note that it is impossible to turn the rocket in an angle of 45 degrees (assuming the 
computer screen is square). Typically, students from Grade 6 through to
undergraduate engineering and physics, start the space-ship moving by pressing K. They wait until the space-ship has nearly reached the top of the screen and then quickly press R three times. (Davis pp. 350-354).

2. John Clement, James Kaput, Peter Rosnick et al.’s “Students and Professors”
Problem: In a college there are six times as many students as there are professors. Use S to shoe the number of students, and P for the number of professors, and write a mathematical expression that shows this relationship”.
(Davis pp. 116-124, 318).

Problem: Take two equilateral solids, where each edge has length L units. One is a pyramid with a square base, and the other has is a tetrahedron (a “pyramid” with a triangular base). Join the two by gluing together two geometrically congruent faces. How many faces does the resulting geometric solid have? (Also how many edges does the resulting geometric solid have?)

(Davis pp. 219-236)

References
Learning to Write [Academically]: A Conversation

From: Student S
To: <jugh@deakin.edu.au>
Subject: Writing Assignments
Date: 9 Oct 2005

Good morning John, Thank you for your suggestions about academic study, and feedback on my first assignment.

I sometimes find it MOST frustrating that I can't put things together in an academic style of writing. Throughout the years I have tried and tried. I am not sure it is something I can learn to do. I wish I could submit a tape to tell you what I know.

I also think it would be beneficial to get someone else to write it for me but using my words. How far can you go before it is collusion or against university principles? Your comments on my assignment are exactly correct. It is overtly chatty, loose, unstructured, etc., etc.

Unfortunately that is how my brain is when I try to put it all together. I'm not sure what to do about it and it worries me.

I am reading Writing at University, written by Les Puhl and Bill Day (both of Edith Cowan University). Do you know anything about it? I hope it can help me, but as I said I do know what to do it is just hard getting it all together. Many thanks
Student S

*****

10 October 2005
Thanks, Student S.

Your question about collusion is tricky. You can, I think, get a great deal of help in the form of FEEDBACK and PROOFREADING, with NO risk of collusion, as long as the feedback and correction is (mainly) on YOUR ideas. However, if the feedback CONTRIBUTES to what you are thinking, so that, in effect, the person providing feedback might be regarded, loosely, as a CO-AUTHOR or as a CO-contributor to the ideas you end up using, then this may be a form of collusion.

You can cover yourself fairly easily. You are EXPECTED to get ideas from OTHER people. When you get the ideas from books and journal articles and web-sites and conferences, you are required to say so, and cite sources. On the other hand, if you get ideas from colleagues, as unpublished oral sources, you can acknowledge this as "PERSONAL COMMUNICATION".

The point is that "COLLUSION" occurs when you have worked with other people and NOT acknowledged this. It is similar to "PLAGIARISM", which occurs when you use other people's ideas and do NOT acknowledge this. Both are forms of
intellectual THEFT, and intellectual DISHONESTY. Neither accusations apply when you acknowledge your sources of information and guidance.

Of course, it is NEVER appropriate to have someone else WRITE an essay and for you to claim that it is YOUR work. (I know you are not even suggesting this. I am arguing hypothetical cases.) The exception here is one that would rarely apply in our (mainly) literate age. If a person is INCAPABLE of writing, then it is acceptable to have their ORAL expression SCRIBED by another person. In the process of such scribing or TRANSCRIBING the "scribe" may lightly edit the speaking-author's oral account, adding punctuation, eliminating pauses and self-corrections, and fixing parts-sentences, and so on. But the scribe is not allowed to add his or her own ideas to the transcription (except where this is acknowledged as an "EDITOR'S NOTE", or something similar).

In rare extreme cases of certified DYSLEXIA, in some Year 12 and university examinations and assessment, a scribe may be allowed to write out what the dyslexic student dictates. But this must be done under strictly controlled conditions that legitimise and constrain the role of the scribe.

(I don't think this is what you have in mind. But knowing that you work in Special Education, I mention it, because you need to be aware of these possibilities.)

No, I am not familiar with Puhl and Day's advice for writers. But I expect it will say all the obvious things, as so many other books do. I probably say the same things, also.

Note, at the outset, that the word "chatty" is crucial. We ALL think, and speak, in a way that is, initially "chatty". That is natural: there is nothing wrong with it. But it is NOT an effective, that is, efficient, form of WRITTEN communication (and may not be effective, sometimes, as oral communication, either).

I can't claim to be a teacher of writing. But from what I have learned, myself, and read (e.g. Donald Graves discussing what is called "process writing" -- PETA, the Primary English Teachers Association [of Australia], the national leaders in Language Education method and theory, have promoted Graves for a long time as a "guru" on how to teach writing) the TRICK or KNACK is to imitate a suitable model or the style of an appropriate model. In this case, you should aim to model your own writing on the style of a "standard" journal article.

I would, I must add, say exactly the same thing about your suggestion of drafting your ideas as an audio tape. There is a huge difference between listening to someone saying, in any way and in any order that springs to mind, whatever improvisatory ideas they have on a topic, contrasted (and it is a huge contrast) with listening to someone speaking in a controlled, considered, structured way.

The key, in both cases, writing or speaking, is in the REDRAFTING. It makes sense to start with a fairly free ramble around a topic. But once you have jotted down everything you want to say (and possibly other things that are less directly relevant, but which at the time seem connected, but in hindsight might not be obvious to a listener or reader, and might be judged as NOT sufficiently on the topic), you need to
consider, from the point of view of your listener or reader (your AUDIENCE), how you
can most effectively, and convincingly, present your arguments.

At this point it may be helpful to use a TITLE as a way of identifying as clearly and
precisely as possible, what you now think your topic is: the MAIN argument, or main
focus of attention.

Then ask yourself what are the main ideas you are going to consider, and summarise
those, in an introductory way.

You could also reconsider the accumulated jottings, and ask yourself, what
QUESTIONS are these jottings ASKING and then ANSWERING? Use the questions
as headings and sub-headings, making sure that each question leads logically to, or is
followed logically, by the next one.

The process of setting yourself a guiding topic, and then asking, and answering, a
string of connected questions, gives the argument a shape that would not have been
obvious, in the first free association jotting down of ideas on a loosely focused topic.

Along the way, as you draw on material you have read (quoting, paraphrasing, and
mentioning or naming), you ensure you include the appropriate references, and
simultaneously compile (at the end of the draft you are developing -- all of this in
wordprocessing, where editing is easiest!) an alphabetical list of References, fully and
consistently cited according to the reference style required by your current academic
target.

Similarly, whenever you use a technical term, or mention some resource, provide a
clear definition, and explanation, and some indicative examples.

Through this redrafting, you are working with, and reshaping, the material you
accumulated in the original draft: rewriting, clarifying, expanding, relocating to a
suitable position in the flow of ideas, and so on.

You are, also, continually rethinking, and using your fresh thinking to draft and
redraft as you work. The point is that until you are WRITING, it will actually NOT be
genuinely clear in your own mind WHAT you actually THINK about the topic you
are working on.

Here the major self-awareness CATCH, for unwary thinkers, is that you can FEEL
you know what you think BEFORE you start writing. BUT in my experience, and that
of most other people, it is DURING the reflective drafting of actual WRITTEN words
that you DISCOVER what you think. You literally SEE what you are saying, and also
seeing what you CAN "say", with your writing.

Before you can see actual words on paper, you only have NON-VERBAL and PRE-
verbal INTUITIONS. These can FEEL clear, and sensible. But in my experience they
can be extremely deceptive. There is, and most experienced writers agree on this (as
do most artists, and musicians), a GAP between what we think we know and mean to
say, and what we find we actually DO say.
To the extent that, when we have finished polishing the final draft, we still feel that we have not yet captured what we really meant, the experienced writer/artist/composer has some remaining motivation to return, later, and develop fresh thinking and another "TAKE" on the same, or related topic. Apart from the commercial motivation behind the endless writing of novels, plays and songs (for example), this sense that there is MORE to say, or that the earlier ideas may have been wrong, or flawed, and need to be clarified and corrected, explains why so many writers do so much writing on their themes of interest.

Do all of this until you feel you have covered, and clarified, and structured to the point where you have said what you want to, as well as you can.

Then, if there is still time, try to leave the polished draft for a day or two (or longer), and then very carefully PROOFREAD it, reading it slowly, ALOUD, to yourself, checking the words at a technical-format level of spelling, grammar, punctuation, and layout.

While doing this technical proof-reading, simultaneously resist the temptation to skim over the actual words, because you KNOW (that is, you ASSUME) they are correct and clear, and say what you mean (because it is always possible that we may not have written-verbally "said" what we mean, but only assembled some words that loosely relate to the vaguer ideas we had in our head), while also leaving some room (mentally) to reflect on the ideas themselves.

The point is that, through these final stages of proofreading, you should give MOST attention to the technical checking (spelling, punctuation, grammar, consistent citations, and so on: the formal apparatus of writing). But you will, naturally, also be continuing to think about the ideas you are trying to convey. Don't let this natural thinking about the ideas distract you too much from the technical checking. But do let yourself benefit, in as controlled a way as possible, from this continuing opportunity to reconsider what you are trying to say.

Later, much later (in the case of assignments, after they have been marked and returned), reconsider your polished draft. It is NOT too late to redraft, and correct, and polish. (Of course it is too late to resubmit the assignment. But I have in mind the large goal of learning to express yourself in writing.) The point is that we can develop our expressive writing ability IF we give ourselves enough practice of drafting and RE-drafting, and, CRUCIALLY, what helps us redraft most effectively is being able to see our draft as OBJECTIVELY as possible.

Here is another CATCH. While we are in the early stages of drafting and thinking, we are so immersed in our own ideas, intuitions, and drafts of words on paper, that it is difficult for us to READ the actual words on paper, and see and consider them OBJECTIVELY, that is, with the fresh objective eye of someone who is NOT immersed, as we are.

But, if we can make a revised draft, and set it aside for some time (at least ONE day, but one week, is better, and one month is better still, and maybe even longer), then when we return to reconsider and redraft, we are NOT as immersed as we had been. We see the actual words on paper in a way that is closer to the fresh way that they are...
seen by someone who has not been thinking (mentally) about these ideas as we have. That is, some while after making the revised draft, we forget the potentially confusing intuitions and non-verbal and pre-verbal ideas we had experienced while we had been making the revised draft. Having forgotten these informal, intuitive, not-quite-verbal ideas, we read the actual words on paper, and THEY stimulate ideas afresh. These words-on-paper are what we think about, not the much vaguer thoughts we had begun with.

Having said all of this about WRITING, I want to add, as emphatically as I can, that SPEAKING is NOT a solution. While I accept that some people are GOOD at impromptu speeches, in my experience, the same kind of drafting and redrafting, ORALLY and possibly LITERATELY (on paper), lies behind the best improvisatory speakers. We may believe (but we probably deceive) ourselves that we speak clearly and coherently, on topics if we just "say what we think". I would challenge you to try to use a TAPE-RECORIDER, and consider (in as objective a way as possible -- tape one day, and listen to the tape a week later, for example) your ORAL-DRAFT, assessing its clarity and focus.

It is extremely challenging to try to use SPEECH to convey ideas directly, clearly, and efficiently. Unfortunately, we are usually NOT the best people to judge how well we communicate orally, because we are too close to what we are thinking and saying simultaneously, and hence judge ourselves SUBJECTIVELY.

The same catch applies: being immersed in our own pre-verbal (pre-oral) and non-verbal THINKING, we struggle to judge objectively the ORAL words we use to capture and express our informal, intuitive, vague thoughts.

The central point here is a fundamental one in any attempt at human communication. Specifically, THINKING is NON-verbal and PRE-verbal, and vague, UNTIL we express (however crudely and approximately) what we think we are thinking in objectively examinable words.

This is NOT easy to learn, in that, simply reading my notes and tips, above, will not miraculously turn a week writer (or speaker), into a clear verbal communicator. But, according to Graves (and others), with extended experience of drafting and redrafting, and with critical analysis and feedback (from ourselves, and other "audiences"), we slowly improve.

I hope this is clear, and that some of this is helpful,
John
Hi John. I am in a bit of bother and need assistance. I am very upset at the moment as I may have left my run for Assignment 1 too late. I have a problem with leaving things to the last minute. I will admit I have been putting this off as I have a real fear of study. This is not an excuse it is real and it is my own fault I know because I know I have to be more organised and even though I do take medication some times it all gets on top of me and I can't function as I should. To this end I really do want to study my degree and have made a resolve to get some assistance with planning study and actually following through.

I would like some assistance in how to set up study for myself where it is not overwhelming.

I do not want to lose the opportunity to study my degree as it has taken me a lot to get to where I am.

I have not engaged in the on-line discussion and have only been reading the materials. This is typical of me, just reading snippets here and there and not focussing on what is required from the very beginning. When I read your email and got onto the unit’s on-line web-discussion I was mortified to see how much on-line discussion had gone on and what I had missed all because I didn't read the bits about having to be involved in the discussion. Purely my fault and I take full responsibility. Please advise me of what you think I should do as I am beside myself with worry at the moment.

Student S

P.S. I have a learning difficulty but don't like to say too much about it because all my life it has been " Student S has the potential but not the motivation", etc.

I was finally diagnosed with Attention Deficit Disorder (passive) (ADD) when I was in my late 20s. I find it gets so much bad press and many people don't believe in it that I tend to clam up. Please help me as I really do want to do this. I do have the ability: I am just a bit scared and obviously I have left it too late to engage in the on-line discussion. I have never studied like this before and have only done external study where you read the materials and then right the essay. I could write the essay but I haven't been on-line.

Student S

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29 August 2005
Dear Student S,
let me start by offering some reassurance. You are not the only one who has NOT been digging into the unit’s on-line DSO web-discussion.
Naturally we encourage students to do so, as it can be very helpful. But on the other hand we do not penalise students who are either unable to do so, or who, for whatever reasons, choose not to do so, or who even, as in your case, accidentally overlook the recommendations to do so, and then discover to their dismay that there is a hole in their study.

That is: you will NOT be penalised for your (so far) non-contribution to on-line discussion. It is NOT tool late to contribute. Feel free to respond to messages, or post your own messages, without having to be embarrassed by introducing yourself so late in the semester. No one will say anything about your late entry. Nor do you need to say anything about ADD (although you are probably not the only one with that condition).

Let also emphasise that the major focus for this unit centres around the two assignments. I assume that, however patchy your other reading may have been, you have identified this focus early, and have been, in your own way, as well as you are able (given the occasional limitations of your learning difficulty or "style"), working towards this focus.

Even snippet-like reading can be pulled together to build larger and more coherent views. I am sure you are familiar with your own ways of studying, and can work with, or around, the varying levels of attention you can bring to your study. Few of us are book-worms able to plough through massive volumes from cover to cover. I know I don't. Certainly I do, occasionally, read whole books. But a lot of my academic studying has always relied on snippet-like sampling, and (luckily) a retentive memory that can fit separate fragments into seemingly sensible larger structures.

Ignore the bad press of ADD. In educational circles it is a familiar condition, and there is no stigma to be frank in acknowledging you are different in this way.

Now for your big question.

I am not an expert on ADD. However it seems to me to be commonsense that if you have difficulty focussing on work, and maintaining attention, then one simple solution may be to break the work down into manageable small parts.

For example, faced with a large and potentially bewildering Unit Guide or Study Guide or textbook (as in our unit), read this as well as you can to find the major focus, and/or contact the unit-chair (or coordinator — the person in charge of the unit, as I am, for this unit) and ask that person to advise you about the focus. Once you identify the MAIN POINT of the unit (in our unit it is "assessment as it operates in and affects my own work") all the other details of Unit Guide and Study Guide and other unit materials will be seen as incidental, or sub-components of the major task at hand.

That is, see the main outline of the wood, despite the potential confusion of all the trees. (Is this metaphor clear?)

My advice, as you now know, is that the focus is the two assignments. There is much more that I could say about this focus (and the Unit Guide says a lot more), but if you
grasp the way the assignments shape everything you do in the unit (and in most Deakin units, where the students' major experiences centre around the assessment demands of the unit) then you can read, in snippets or in any way you can manage, with this central focus guiding your reading and helping you fit the bits of reading together.

Another tip for maintaining attention and focus.

From the outset, as soon as you receive the study materials for the unit, make yourself a time-line for ALL the remaining time for study, including any remaining weeks up to the actual formal beginning of the semester, onwards through the semester to the end of the formal study period.

Then enter on this personal study-schedule the assessment deadlines.

Then plan backwards, in reverse chronological order, the tasks needed to achieve the deadline.

For example, you might allocate one week of the study-schedule to each of these tasks that build an assignment.

— SUBMIT the assignment.
— REVISE the final draft, and check referencing formats.
— WORK on early drafts.
— START first draft.
— MAKE detailed notes about ideas to include in the discussion.
— FINALISE the TOPIC of the assignment: make this in the form of a question which is later to be answered by the discussion which will be drafted.
— READ widely on topics of interest, and general background for the unit.
— CONSTRUCT a study-schedule, including identifying the official statement about the "assignment" prescribed by the unit materials.
— FAMILIARISE yourself with the unit materials.

If each of these points takes a whole week, this may be longer than you have available, within the semester. But usually Deakin tries to mail out unit materials several weeks earlier than the official beginning of a unit.

Of course, you should treat any study-schedule flexibly.

Make your draft schedule, and the available time, work for YOU, rather than making IT work you, or dictate to you. (Is my intended emphasis clear, here?)

If you finish one of the steps earlier than the whole week, then proceed immediately into the next stage. If you need extra time to complete a stage, do so, but don't panic about doing this, and be willing to modify the schedule, while maintaining the focus on the END-POINT and the deadline for submission.

It is also helpful to try to have a specified TIME for studying. This might, for example, be 8 p.m. to 10 p.m., seven days a week (or as many days as you can manage). Or it might be ALL of Sunday, or all of Saturday and Sunday afternoon, 1 p.m. to 6 p.m.
Try to stick with your self-determined time-table for working. But be willing to be flexible (to accommodate social occasions, changes in weather, or similar unpredictable and incidental events). But don't feel guilty if you stray, occasionally from the time-table: that is, don't let your guilt about NOT being well organised become an emotional cause of further disorganisation. Tamp down any tendency to panic, and work as coolly and steadily as possible.

Moreover, as soon as you know what units you are enrolled in, you can use the Handbook Entry for each unit as a guide to general background reading for the unit, and begin this introductory and largely self-directed reading, weeks earlier than the actual arrival of posted unit materials.

For example, for each unit, as soon as you know you are enrolled in the unit, use the broad outline of the unit, as given in the Handbook (the unit title is often a handy guide, as well as the outline of the content of the unit), as a guide for the following tasks:

• GATHER any materials that are broadly on the unit topic that you already own (from undergraduate study, teacher-training, professional development, or other study);

• CONSULT with colleagues about what they think might be relevant to the unit topic, and especially seek BRIEFING by colleagues who have studied this unit or similar units in other institutions;

• BORROW any materials on the topic, using general professional resources of your school or institution, and any materials your colleagues can lend you;

• REVIEW (however snippety) all the materials you can gather;

• REFLECT on your own existing ideas and experiences of the unit's topic, drawing on your own life when you are a student as well as your working life as an educational professional.

All of this can be going on through Deakin's summer break, or between the end of one semester and the start of another. This may mean you spend some of what would otherwise be "holiday" time on what would ordinarily be regarded as "work". But you are doing this because it will help you cope better during the official "work" or "study" period of the unit.

Use notebooks, or any similar devices, including wordprocessing, as ways of shifting any occasional incidental ideas and experiences OUT of your head, where the ideas occur, and into written prose that captures your ideas.

Good note-taking, while reading, in whatever snippety fashion you usually manage, will help you RECALL the striking ideas you encounter, as you read. (DON'T fall into the misguided trap of HIGHLIGHTING everything you read, or trying to painstakingly make notes of every point you come across. Let your note-taking be a natural guide to the genuinely interesting and important ideas you encounter -- those rarer, but special moments in the reading.)

As I said, I am not an expert on ADD. I assume my suggestions are either similar to what you already naturally do, anyway, or may be unhelpful. But you may also be guided by general tips on how to study, with and without ADD (via books, self-help
materials, internet resources, or chatting with colleagues about their own work-habits). Schools tend NOT to teach students HOW to organise themselves to work efficiently. Hence, students invent their own hit-or-miss methods. It is valuable to pause, and consider HOW you ordinarily work, and discuss with other people how they work, and then consider, in the light of this reflection and consultation, how you might modify your own work-habits to make them more effective, for you.

As for on-line discussion, and the demands of computer-based writing, the following comments may be relevant.

I must confess that I started teaching myself two-finger typing on a very worn-out Corona (or Royal?) manual typewriter when I was about 10 years old, around 1960 (yes: I am that old!).

Later, as a young university lecturer, having spent my entire time as a school and university student, and a classroom teacher using nothing more sophisticated than handwriting and spirit-duplicators, I started using electronic typewriters, including CORRECTABLE typewriters (they had a roll of white-out ribbon that could be activated by back-spacing to a typo, and typing over it – it meant that EDITING had to fit in the space of any text that was being deleted and replaced; or that editing had to be based on physical cutting and pasting of correctly typed portions of text, or involved completely retyping).

I mention all this because I now find myself with sufficient typing speed, and experience, that I can compose fresh prose almost as fast as I can type.

I can also read fairly comfortably by simply looking and scrolling through the computer screen.

Hence, as a fast-enough typer and capable screen-reader, and a BOOK-MINDED person, I feel that I can virtually “SPEAK” to you, in a virtual-face-to-virtual-face-way.

Teaching on-line is a NEW way of teaching. But to me it feels very similar to actually listening and speaking in an ordinary classroom.

BUT — and this is an enormous “BUT”— EVERYTHING THAT IS VIRTUALLY-SAID can be EDITED, and SAVED. Hence everything that is typed can potentially contribute to academic work, at my end, as well as at yours.

Compare this with a real-life face-to-face classroom.

People can speak all they like in a classroom. But at the end of the day, or lesson, they rely on their MENTAL MEMORY, or on their HANDRITTEN MEMORY, or they leave the classroom remembering very little. The sad reality is that most students who sit in a real classroom listening, will retain in their memory maybe ONE fresh idea from that class — UNLESS they keep good hand-written notes of the MANY things that are SAID, and DONE, and DRAWN or DISPLAYED in that class.
Thanks to my trusty hard-drive, I can leave a lot of my remembering to my computer. It frees me to think, and to use what I virtually-say, and to teach,

I hope this is clear, and that some of it may be helpful,
John