Design and Technology Educational Research and Curriculum Development: The Emerging International Research Agenda

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INTRODUCTION

Eddie Norman
Co-Director IDATER

The publication of book derived from IDATER conferences (as distinct from Conference Proceedings) is a new venture for IDATER, which has been undertaken in order to further the debate concerning an international research agenda. It is hoped that this publication will both enable those who were not fortunate enough to be at IDATER99 and IDATER2000 to gain something of the Conference outcomes and help to prepare for IDATER2001. The scene is set for the selected Conference Opening and Keynote Addresses by reprinting the invitation to IDATER99 (previously published in the pre-Conference Handbook for IDATER99 and on idater-on-line). From 1988 to 1998 IDATER played an essentially passive role and provided a forum for the discussion and dissemination of the best available contributions to design and technology research and curriculum development. The drivers for this research were essentially derived from emerging practice and the researchers were immersed in the issues of the day. There is evidence that this research area is maturing and there have been consistent suggestions – even expectations – that IDATER should play a more proactive role. It was in response to these promptings that the 'invitation paper' to IDATER99 was written.

Discussions about the emerging research agenda have always taken place at IDATER through the mechanism of Special Interest Groups (SIGS). In the past 'values' and 'primary' were IDATER SIGS. SIGS were established by the delegates not the Conference Directors and hence the discussion of the emerging research agenda was driven by the delegates as part of the 'running conversation', which is at the heart of any good conference. However, as part of an exploration of an additional mechanism a research seminar to discuss international research collaboration was organised as part of the IDATER2000 Conference Programme. This event and the plenary discussion led to an increasing demand for the facilitation of international research collaboration as part of IDATER2001.

So this book has two roles. Firstly, to support the seminar programme concerning the benefits, priorities and approaches to international collaborative research which is an integral part of IDATER2001. Secondly, to bring together recent contributions to IDATER that have addressed the general issues facing researchers in this area (rather than those relating to particular countries or cultures). It is from these, and similar, general contributions that the international research agenda would be expected to emerge.

This picture has been completed by including a list of all the papers published at the previous thirteen IDATER conferences, which began in 1988. The abstracts of most of these papers are available through the IDATER website and work is continuing to make them all easily accessible. (Abstracts were not included in the early years and therefore need to be written.) Together with the Keynote Addresses these constitute a substantial part of the design and technology education research base during its pioneering years.

An invitation to IDATER99

Phil Roberts
Co-Director IDATER

1. The object of IDATER is to contribute to and raise the level of the professional ‘running conversation’ about design education. (This term ‘design education’ is used as a hold-all, to encompass the range of terminology and curriculum subject titles that is used internationally.) A ‘running conversation’ is the essential means by which knowledge and understanding of design phenomena and of designing are increased and enhanced, and, for IDATER, the curriculum and pedagogy. Participation in the ‘conversation’ is a necessary condition towards such development. The ‘conversation’ needs a Research & Development map and agenda: both are incomplete.

This invitation is offered as a first step towards reviewing both, and, consequently, developing further the professional conversation.

2. Everyone – infant or adult – engages in the intentional activity we refer to as ‘designing’. In this general sense, ‘designing’ refers to acting in and on the world; to bringing about some required change in the world (or, in the educational context, in ourselves); to achieving ours ends by the agency of designing.

Some adults are, also, members of professional communities of practitioners (eg, architects, industrial designers, teachers, town planners) whose practices, at the highest level of commonality, are related by their being grounded in design and its activities. This is, then, an all-encompassing range of participants.

Because we are all immersed in the subject matter of design, and because the capacity for design is a fundamental human capacity, the development of the design capacity is a proper part of general education. Attention to design phenomena and to designing is a similarly necessary part of the education and training of those professional practitioners whose work is grounded in the field of design. We all engage in designing irrespective of its presence (and, our attendance) in formal education: hence, ‘everyone is a designer’ provides the first arena of design activity. In formal general education, we attend to the development of design ability throughout the period of statutory schooling: statutory education is the second arena; and the formal education of particular specialist professional groups of (especially) practitioners attends to the development of knowledge and understanding of and competence in design and designing, (in the third arena). Notice that design and designing are addressed in all three arenas. Notice, too, other things.

The three have significant dis-similarities; the ‘same’ terminology of design does not necessarily transfer from one arena into another; the ‘same’ activities in professional designing and in general education do not serve the same functions, nor the same purposes. Hence, conflation of the three arenas (when speaking of designing) is something to be avoided, or at least, to be wary of. The unexamined notion, too, that a context-specific conception of would-be educative activity can be sensibly transferred from the education of the professional practitioner to the curriculum of pupils in general education is surely mistaken. The unexamined notion that a particular model of artefact-achieving provides the core model for general education is surely to mistake a low-level and particular instance for the high-level and general case (as well as to fail to distinguish between artefacts as ends in themselves and the making of things as (incidental) means towards educative ends). On the international scale, the notion that one country's not-necessarily-very-well-founded curricular arrangements can provide a model for the circumstances of a quite different society is surely wrong, based on naïve notions of transferability and an ill-considered ethical position.

3. As long ago as the 1970s, Bruce Archer drew attention to the taxonomy of Design: '…..a discipline needs a language, a taxonomy, and a metrology. (…) where are the tools of language, taxonomy and metrology capable of handling the central issues of Design …? (…) The taxonomy of Design (…) is a hotch-potch of classifications drawn from many disciplines or sub-disciplines, and having no underlying structure at all. The metrology of design is almost totally deficient in the techniques of comparing and ordering important, non-quantifiable qualities like usefulness, convenience, ethics and style.' [1]

Taking the organisation of other more-developed disciplines as a model, Professor Archer suggested a framework for a knowledge base in design:

0 *design technology:*

the study of the phenomena to be taken into account within a given area of design application;

1 *design praxiology:*

the study of design techniques, skills and judgement applied in a given area;

2 *design language:*

the study of the vocabulary, syntax and media for recording, devising, assessing and expressing design ideas in a given area;

3 *design taxonomy*:

the study of classification of design phenomena;

4 *design metrology:*

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[1] Design in General Education (The report of an enquiry conducted by the Royal College of Art for the Secretary of State for Education and Science) Part One: Summary of findings and recommendations. London: Royal College of Art 1976, pp. 39-40.

the study of the measurement of design phenomena, with special emphasis on the means for ordering or comparing non-quantifiable phenomena;

5 *design axiology:*

the study of goodness or value in design phenomena, with special regard to the relations between technical, economic, moral and aesthetic values;

6 *design philosophy:*

the study of the language of discourse on moral principles in design;

7 *design epistemology:*

the study of the nature and validity of ways of knowing, believing and feeling in design;

8 *design history:*

the study of what is the case, and how things came to be the way they are, in the design area;

9 *design pedagogy:*

the study of the principles and practice of education in the design area.

4. Such an organising framework could make more coherent the diverse contributions offered by researchers, scholars, and practitioners working in numerous disciplines and research communities. Its usage might also enable greater coherence to be made between the different intentions (and outcomes) of those working within general classes of research activity. Consider the following five classes:

1 *fundamental research*: that is, systematic investigation directed towards acquisition of new knowledge, the establishment of principles, or the formulation of defensible explanations;

2 *applied research*: that is, systematic investigation directed towards the exploration of the implications or consequences of the application of fundamental principles in particular situations;

3 *action research*: that is, systematic and reflective activity, carried out by practitioners and grounded in their experience, directed towards the resolution of practitioners' problems; or towards the acquisition of information as grounds for decision and action;

4 *pedagogical research*: that is, systematic enquiry/activity directed towards the greater understanding of curriculum, principles and practices of teaching and learning, skill acquisition and performance assessment;

5 *studio research*: that is, systematic investigation through art and design action, calculated to capture and expose ideas and information having testable validity within and beyond the work(s) in which they are embodied.

5. Given that IDATER is concerned with the design curriculum and its associated pedagogy, practitioners (which, it is to be taken as read, encompasses teachers, working in whatever level) have a major role to play. Action research and pedagogical research, particularly, are the most generally accessible to practitioners.

Leaving IDATER aside for a moment, two (and perhaps three) main trends are discernible in the analyses carried out by design curriculum reformers on the past 15 or so years in the UK. The first has stressed the need to institutionalise the whole process of (what would be) continuous review and development of their practices by practitioners, and seeks to explore what would be the reality of such a 'steady change state'. The second has sought to confirm and develop professional responsibility for 'bottom-up change' (as distinct from merely accepting 'add-on' and incidentally unachievable, 'top-down' impositions). The two are sides of the same coin. (The third trend, even more radical and ambitious, would wish to see the gap between the policy- and decision-makers' level and the practitioners' level lessened so that more-realistic policies might be formulated in the first place.) (In connection with these trends, see para 6, below.)

Both trends can be seen, in part, as the practitioners' response to the absence of an adequate infrastructure for broad-based planned innovation and change, and to the absence of a practitioners' research tradition (or, running professional conversation). Implicitly, both aspire to contribute towards a theory of design curriculum and design pedagogy that would be grounded in practice: a practitioners' theory. That, too, is radical (and not all practitioners wish for such responsibility).

6. It might be useful to draw attention to another factor. It is obviously necessary that public education be dealt with at the level of policy and strategy. But irrespective of that, the essential design agenda – and, by extension, the design educational research agenda – is the perennial research agenda. It is to do with the nature of the design capacity; with the development of design ability, sensibility, awareness; with the phenomena with which we treat when we are 'designing'; with the relations between these and, further, with teaching and learning.

But the introduction of national curricula does not necessarily change that perennial research agenda – although it certainly adds to it. What the introduction of national curricula typically introduces, are problems deriving from the requirement of implementation. That is, problems arise precisely from the demands to achieve specified end-states of policy ('The pupils will be able to do (this, that, and the other)'). The imperatives of the implementation of policy do not necessarily coincide with the imperatives of fundamental research, nor even of applied operational research and development. But the top-down introduction of essentially prescriptive curricula brings into being a range of issues which arise directly from the requirement of implementation; the 'transfer' of one country's plans 'into' another country brings yet another range of issues.

It is the implementation requirement that has perhaps the greatest potential for hindering progress in fundamental and scholarly research (as well as operational research and development activity). It is easy to accept that the process of working towards policy objectives may throw light on fundamental issues. But the essential focus of implementation is not on enquiry into and the analysis of fundamentally problematic phenomena: it is on implementation; and implementation is a condition in which the perennial research agenda may remain untouched. This is not surprising: the receivers of policy – the practitioners in the field – are 'merely' required to implement policy objectives. Never mind that the policy may beg the philosophical and operational questions: the object of implementation is a match with specified policy objectives, not the questioning of the well-foundedness of policy. Moreover, even were the distinctions between problems located in a fundamental research agenda and those which arise from the required implementation of policy more frequently distinguished and less rarely conflated, it is not as simple even as that: policies are predicated on ideology.

Public policy and ideology may have an obvious connection but are rarely explicitly distinguished. Even more rarely is the ideological basis of much public policy made clear. Research projects which may be established to support the implementation of policy are also obliged (if they wish to continue) to work within the ideological framework.

On this view, the introduction of (any) national design-related curriculum can perhaps most usefully be understood as an episode in the continuing cultural evolution of design in education and society. *The implementation of an ideologically-loaded policy does not necessarily diminish, or remove, or resolve any of the perennial and fundamental design research agenda.*

Indeed, there is always the possibility that the introduction of any putative 'reform' may burden further that research agenda. That some development work may intersect with research, both in its process and in its subject matter, serves to illustrate this proposition rather than to alter it. The nature and logics of research activity and the nature and logics of the implementing of public policy are different. Research agenda and research enquiries are based on the absence of certainty and, typically, begin from an inadequate knowledge base. Much public policy displays, in contrast, an absence of doubt.

7. First, having in mind Professor Archer's framework for a knowledge bas in Design, we can move to a starting point for, no doubt, numerous future research agenda for IDATER participants. Most of IDATER's research agenda, however, are likely to be focussed on design pedagogy, praxiology, technology, and epistemology. Hence, ranging between the perennial and the context- and time-dependent questions:

1 What is *the nature of the design capacity and its functioning*? (That is, the capacity that is necessarily engaged when treating with design phenomena.) Or: *How is it possible to design (or take action in and on the world) at all?*

2 What are the distinctive *natures of design phenomena* with which professional designing, designerly, and design-educational activities treat? (That is, typically and distinctively, the real-world problematic states-of-affairs; (and noting that the activities of designing cannot be disconnected from the objects of their agents' attention).)

3 What (and whose) *developmental 'stages', needs, attributes, aspirations, hope, and values* are to be attended to when engaged in learning-through-designing?

And, to the more context- and time-dependent questions:

4 *How is the design capacity developed* (ie, towards design *ability*) *through deliberately organised activity, or learning-through-designing?* (That is, what do we need to know and understand better about the nature of the curriculum and its associated pedagogy?)

and

5 *What knowledge, competence, intellectual and personal qualities, attitudes, and values* would be appropriate to being at ease with the conditions of the 21st century, and can be developed through design-educational activities?

and

6 What *cultural, societal, economic, ideological, political, technological, (and other) contexts, dimensions, and factors* require consideration of their present and future effects and influences?

and

7 What effects do the *diversity and, essentially, the constraining factors of educational (and other) institutions have on 2-5, above?*

And now, the invitation is to suggest the general and the specific questions; the sets of questions; the topics; the problematic complexes of issues; the specific agenda that, being acquired into systematically, would provide some clothing for the taxonomic skeleton as well as contribute to the development of the curriculum and pedagogy.

When thinking of such matters, consider, too, which can be well, or best, addressed by practitioners-as-researchers (of whatever kind and in whatever field of practice); consider the distinctions (where they exist) between research and development, and the different classes of research; consider which matters can be best, or only, addressed by researchers and scholars (and practitioners) in other disciplinary fields: they can offer, at least, insights of value; and consider which can be best, or only, addressed through collaborative efforts in research, scholarship, and development.

From the contributions received during and after IDATER 99 we shall endeavour to produce a map (or, even, sets of maps), and an agenda (or, even, a range of general and specific agenda) for distribution to IDATER and beyond.

OPENING ADDRESS TO IDATER2000

Aspects of Research Concerning Design Education

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The objectives of the paper are to support the conduct of action research by teachers-as-researchers and, thereby, contribute towards the development of (1) design educational practice and (2) the 'ideas cultures' inhabited by teachers. The emergence of conceptual distinctions relating to design education over the past 25-30 years is indicated. These are seen as signs of significant paradigmatic shift and of a nascent language of discourse. The Design field is distinguished; attention is drawn to the status of cognitive modelling; to an academic framework that might be helpful in developing a knowledge base in Design; and to differing approaches to research inquiry. The nature, and particular appropriateness to practitioners, of action research is explored. Some 'big' topics - not always seen as having immediate relevance to everyday pedagogy - are then introduced and considered. These, were they better appreciated, are seen as being potentially beneficial to the 'ideas culture' and the pedagogic quality of the design educational community.

Keywords: action research, teacher-as-researcher, paradigmatic shift

IDATER - the title of this Conference is 'International Conference on Design and Technology Educational Research and Curriculum Development'. If we unpack this a little, the central focus is *educational research*; the key theoretic framework of that research is *the field of curriculum studies* and the *area*, more particularly, is *Design Curriculum Studies*. And there are, too, some crucial *distinctions* to observe - between *Design* (as a field of human enterprise and endeavour) and *design education* (which has distinguishable areas and levels of attention, practice, and specialist communities), and *Design & Technology* (which, in the UK, is the name given to a particular school curriculum subject in general education). Let's keep these in mind.

My objectives are these:

to support ACTION RESEARCH as a mode of inquiry and development that is especially appropriate to D&T educational practitioners;

to support the TEACHER-AS-RESEARCHER (or practitioner-as-researcher);

to support the position that action research within education (and D&T education) is intended to improve practice;

to note, therefore, that action research in education differs from other research paradigms; and

to suggest that useful connections can be made between the high level of abstraction and the experience of everyday practice.

In general, practitioners never appear very enthusiastic towards theory, (nor towards research). Yet all practice is embedded, implicitly or explicitly, in theory.

In education, the work of the past 20 or so years in Curriculum Studies has made increasingly apparent the problematic nature of curriculum phenomena and of pedagogy. Academic researchers, scholars, and practitioners working in the field of Curriculum Studies seek to contribute towards the development of knowledge and understandings as an integral and necessary strand in the development of practice. The review and development of pedagogy, necessarily, starts from the complexities that are sensed and experienced in practice. Practitioners are hence well placed to make major contributions towards the development of practice and curricula. Curriculum Studies is a practice-led field; it is not led by the problems that are within the formal theories of those disciplines that are associated with education; it is also methodologically eclectic (which is not to say idiosyncratic).

'Design education' may be a relatively recent addition to the professional educational vocabulary – in the past 25-30 years; D&T as a school subject tag (in the UK) is newer still. But design phenomena are not new at all; the idea of human beings having a capacity for design is not new; the idea of doing and making as central to human being is not new. The foci of attention in design education may be new; the emphases within general education have also changed. Some of the substantive questions/matters that have been addressed in the past 20-25 years in Curriculum Studies have been overtaken by the continuing conversation; others have stayed the course because they are perennial issues. Some of the matters that have been overtaken remain interesting, historically, because they may help to indicate, for instance, 'stages' of conceptual development or suggest the evolution of methodological approaches.

Some of those matters that have been overtaken can, now, be understood as contributions *of their time* within a wide-ranging professional conversation, and, more particularly, as attempts to contribute to the developing *language of discourse*. The idea of a professional, and alive, conversation is important in any field. It is perhaps particularly so in a time of rapid change for well established areas of practice. Other factors are also significant. Design is a large *field*. The *design educational field* is also large (as well as different); it has *levels* (primary, secondary, tertiary); it contains both specialist and general education; it has distinguishable *areas*; the field contains the several communities of practitioners, many of whom do not necessarily communicate with each other: they inhabit different paradigms and traditions, (and so see the world differently).

Fifteen years ago in the UK, the most usual conceptualisation of the secondary school curriculum would see these different areas roughly superimposed upon the curricular field of Design Education through the usage of such titles, then, as Art, CDT, Home Economics, Textiles/Fashion. The field of Design Education was commonly understood as being related strongly to such subject areas. But no single one of them – nor indeed all of them collectively – represented fully the field of Design, nor constituted the whole of 'design education'. Further, it was not obvious that any of such subjects necessarily offered the exemplary *general* case of design educational activity (though exemplary *particular* cases might be constructed in any of them). The nature of the relations between those curriculum subjects was not obvious either. And now, in the past 10 years in the UK, the tag D&T has emerged and, in schools, has become perhaps the dominant tag. But D&T is just one curriculum subject area; Art - nowadays Art & Design - is another. Design education (in schools) remains a larger field than can be represented by just one or two curriculum subjects; the term, Design, can represent a large dimension of the general educational curriculum; and, of course, design phenomena extend beyond the boundaries of general education anyway.

All of that might be sufficient to indicate that the well-foundedness of 'what we all know' is insecure. But further, across the different subject-based communities of practitioners, even when the subject matter is innocently considered to be 'the same', conceptions may be significantly different. This may or may not be appropriate. But it would certainly be helpful if the differing conceptions, together with the complexity that thereby arises, were to be made more recognisable and comprehensible and thereby acceptable.

Much that is problematic in the design curriculum has a fundamental and direct connection with practice. On this view, the cruder anti-theory and anti-intellectualist stances – or, put differently, the absence of a sufficiently developed language of discourse – become more illustrative of the weaknesses of the field than of its strengths. Consider a particular matter. It can be argued that the essential 'language' of design activity, as distinct from the meta-language of discourse (and, preserving the distinction, of design educational activity) is cognitive modelling. This cognitive medium, or instrument, cannot be represented in natural language: that is, the cognitive medium or 'language' of designing is distinguishable from natural language (and from mathematical notation). But acknowledging that does not imply that that we should despair at our inability to 'put into words' that which cannot be presented in words. But nor does it support the adequacy of falling back on mystification or on professional folk-lore in response to those who ask questions from outside the field: that is to give up too easily. We might, for instance, acknowledge that we necessarily use natural language, in a meta-language, to talk about, to refer to, the relations between designing and other kinds of activity.

There is a need for a meta-language precisely – or, if only – because natural language is not an equivalent to the cognitive non-linguistic medium of design activity. Consider, too, issues to do with the 'content' of the design curriculum. An attitude that is reflected in the question, 'Why reinvent the wheel?' is familiar in discussion of design and design curricular activities.

Why indeed? Taken at its most simplistic, the question naively asserts the view that there is a body of knowledge susceptible to codification, which can be 'fixed' and transmitted, and which would save everyone who follows from the work of constructing (or reconstructing) that knowledge. And yet, the use of the wheel metaphor may also be seen as an illustration of the weaknesses of the field. Some kinds of knowledge may indeed be codified. But the making of meaning, the development of operational competence, the development of design cognition, are functions central to engagement in action. Not all knowledge is propositional. Much design knowledge and knowing is a function of action. It cannot be codified into propositional knowledge. Learning and knowing of this kind is necessarily a function of the action that consists in engaging in and on the world, and everyone necessarily *makes* his/her own personal (and, to an extent, public) knowledge.

So, there’s considerable scope for reflection upon practice and for systematic inquiry into that practice. There's scope, too, for considering the nature of inquiry, and the nature of theory that practitioners would feel more at ease with, (which is to say that it would be, of course, *a practitioners’ theory*). There are, too, competing ideologies.

And then, there’s a further interesting matter that receives very little explicit notice: a significant part of Design Curriculum Studies and its running conversation is also concerned with some of *the conceptual problems* surrounding the development of design education (and, more specifically in this context, D&T education). The conceptual problems are of two kinds, internal and external. Internal problems receive some clarification by practitioners as an integral part of day-to-day work (though they are necessarily resolved). External conceptual problems become especially apparent on the acceptance that ‘design education’ might represent the emergence of a substantial paradigm transformation – one that would be neither subject-bound nor subject-specific. Some might also argue that D&T is indicative of paradigm shift, having handicrafts, metal/woodwork, CDT as its precursors. Paradigmatic change inevitably brings disturbance to the taken-for-granted perspectives and rationales of normal practices. This is easy to suggest; its implications, however, are radical, and their force rarely appreciated.

For instance - but not for pursuing at the moment - the seemingly banal question, ‘What is a problem?’ together with the very different one, ‘When is a problem?’ point both to internal and external problems and disputes. The questions are indicators of quite different epistemological accounts and conceptions of the nature and purposes of design education and of D&T educational activity. The tension between differing theoretic positions and between differing existential persuasions – and, hence, curricula and practices – is made all the more sharp by the belief of groups of practitioners that *their* practices are rationally or self-evidently well-founded. The status of such rationales – often implicit rather than explicit – is matter for analysis.

A new and larger paradigm of practice would be signalled in the general acceptance and usage of new categories. A period of paradigmatic transformation is a source of confusion, disagreements, and criterial difficulties: the frequency of questions such as, ‘What is design?’ ‘What is research?’ ‘What is practice-based academic research?’ indicate the problematic. Further on – indeed, much further on – it is possible to glimpse at least two other salient areas of inquiry emerging. One might have as its focus of attention the cognitive status of and the functions of metaphor in relation to the act of designing and the objects of the designer's attentions. The second area would include a focus on the centrality of values, the processes of valueing, and the *making* of meaning in design educational activity: that is, *the semantic core of designing-as-learning*. But attending to the design educational curriculum is an active and necessarily participant process. Such immersion is also the basis of professional-personal development: it is this that leads to any significant curriculum development. Practice changes and develops as its practitioners change and develop.

All that was Preface. Now to the beginning proper: first, I want to revisit some notions.

DESIGN & TECHNOLOGY EDUCATIONAL RESEARCH AND CURRICULUM DEVELOPMENT

In the 1970s, Bruce Archer offered a simple and powerful model of Design as an area of human activity and significance and argued that Design is as significant as the Sciences and the Humanities. He also distinguished it from both.

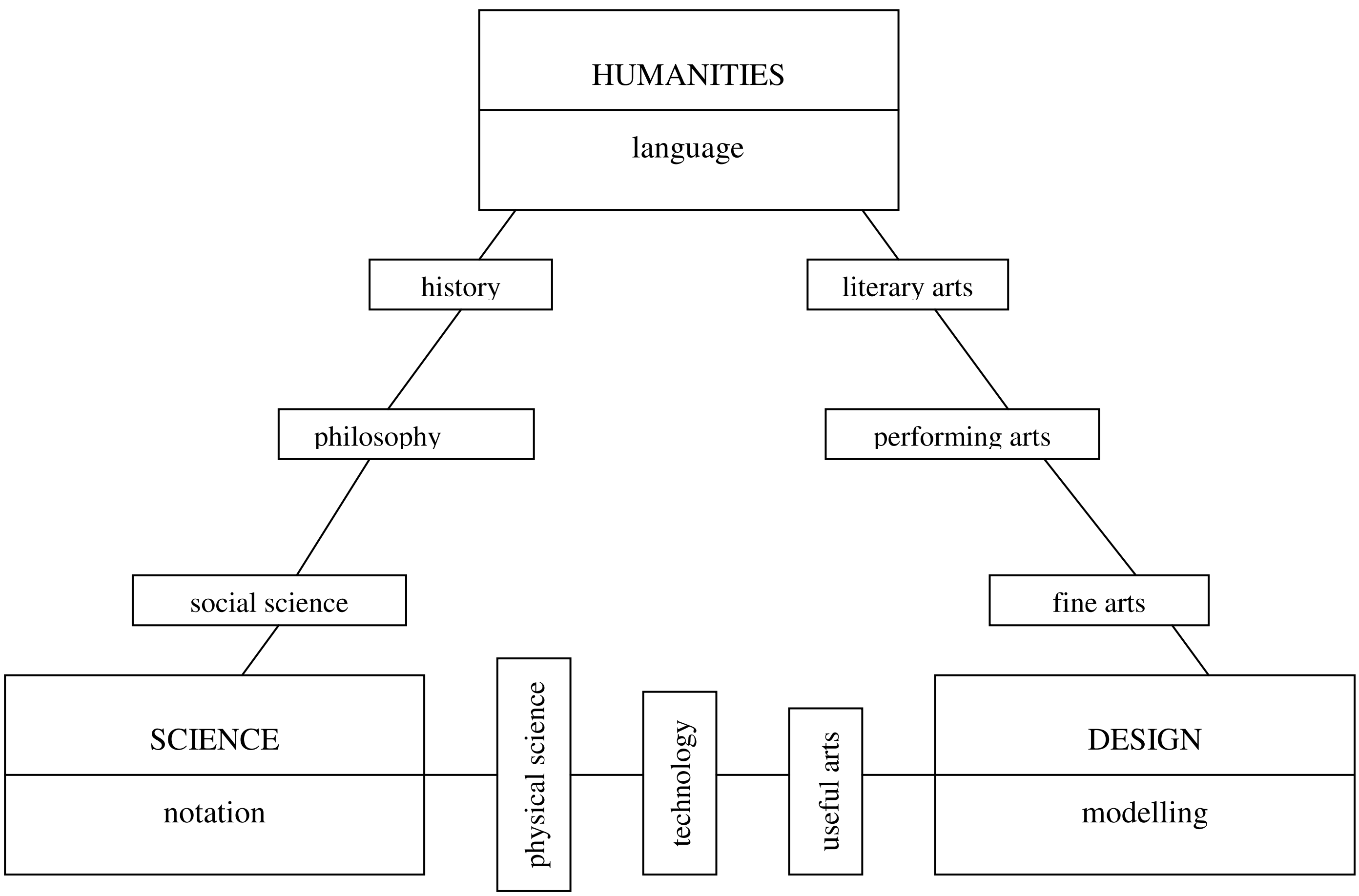

Figure 1: Design as a 'third area' [Source: Design in General Education (1976) pp15-16]

> The repository of knowledge in Science is not only the literature of science but also the analytical skills and the intellectual integrity of which the scientist is the guardian. The repository of knowledge in the Humanities is not simply the literature of the humanities but also the discursive skills and the spiritual values of which the scholar is the guardian. In Design, the repository of knowledge is not only the material culture and the contents of the museums but also the executive skills of the doer and maker.

Archer distinguished Design as a distinctive dimension of human activity, and as a distinct kind of knowledge and knowing;

He identified a distinctive capacity of mind as being engaged in the act of designing, and identified the essential 'language' of the practice of Design and of the act of designing as being *modelling* (or *cognitive modelling*).

WHAT DO WE MEAN BY COGNITIVE MODELLING?

> The conduct of design activity is made possible by the existence of a distinctive capacity of mind, analogous with the language capacity and the mathematical capacity.
>
> This is the capacity for cognitive modelling. A person acting in the role of designer or appraiser of designs forms images 'in the mind's eye' of things and systems as they are, or as they might be, and evaluates them and transforms then so as to gain insights into their structure and into the likely quality of fit between alternative conceivable requirements.
>
> Cognitive modelling is not limited to spatial configurations. Cognitive modelling is independent of language or symbol systems but when appropriate the concepts modelled can be translated into or supplemented by language or notational terms. The image is usually externalized through models and simulations, such as drawings, mock-ups, prototypes and, of course, where appropriate, language and notation, or it can be embodied into the construction or enactment of the emerging responses. These externalizations capture and make communicable the concepts modelled.
> (Archer and Roberts (1979, pp55-56))

Why is cognitive modelling so important? What is its status?

A useful response was offered 20-odd years ago by Janet Daley:

> … the capacity to envisage alternative physical realities and the representation of those alternatives in symbolic forms which are universally intelligible is a definition of design … To present design in this way, ie as a function of the human capacity to understand a physical environment and to represent the

> contingencies, and possibilities of that environment in abstract ways, is to accept what one might call the intellectual status of design.
> (nd, p1)

Now to design research – *academic* design research. Thirty years ago, Bruce Archer produced a framework for a knowledge base in Design (*below*). He used it, amongst other uses, to guide his own research inquiries. There are various ways of using it:as a map, or as a compass; it locates. It can be used, when clothed, to indicate gaps and strengths in our knowledge base of design.

0 design technology

1 design praxiology

2 design language

3 design taxonomy

4 design metrology

5 design axiology

6 design philosophy

7 design epistemology

8 design history

9 design pedagogy

Figure 2: A framework for a knowledge base in Design [Source: Design in General Education (1979, pp39-40)

And, in greater elaboration:

0 design technology:
The study of the phenomena to be taken into account within a specific area of design application or practice, and which, together, constitute a paradigm

1 design praxiology:
The study of the design techniques, procedures, skills and judgement applied in a given area or paradigm

2 design language:

The study of the vocabulary, syntax and media for recording, devising, assessing, presenting and representing design ideas in a given area or paradigm

3 design taxonomy:
The study of the classification of design phenomena

4 design metrology:
The study of the measurement of design phenomena, with special emphasis on the means for ordering and comparing non-quantifiable phenomena

5 design axiology:
The study of goodness or value in design phenomena, with special regard to the relations between cultural, technical, economic, moral and aesthetic values, and ideologies

6 design philosophy:
The study in the language of discourse of moral principles in design; and of the existential phenomena of design experience and activity

7 design epistemology:
The study of the nature and validity of ways of knowing, believing and feeling in design

8 design history:
The study of what is the case, and how things came to be the way they are, in the design area

9 design pedagogy:
The study of the curriculum, principles, and practice of education in the design area

Figure 3: A framework for a knowledge base in Design

When we look at this, it's notable that it's not based on any single tertiary academic discipline; nor on any single professional design discipline or area of practice; nor on a school curriculum subject; but that it is potentially useful to a practitioner/researcher/scholar in any of these. From this, we can move to acknowledge differing approaches to research inquiry:

1 fundamental research:

that is, systematic inquiry directed towards the acquisition of new knowledge, the establishment of principles or the formulation of defensible explanations

2 applied research:
that is, systematic inquiry directed towards the exploration of the implications or the consequences of the application of fundamental principles in particular situations

3 action research:
that is, critical reflection upon practice and systematic inquiry directed, especially, towards the development of practice, or to the resolution of difficulties or problems perceived or experienced by the teacher/practitioner-as-researcher, with the objects of developing the researcher's knowledge, understanding and competence; and/or curriculum or practice; and contributing towards a practitioners' theory

4 studio research:
that is, systematic inquiry through studio/workshop activity calculated to capture and expose ideas and information having testable validity within or beyond the work in which they are embodied

5 pedagogical research:
that is, systematic inquiry directed towards greater understanding of curricular phenomena, the principles and practices of learning and teaching, skill acquisition and performance assessment in support of teaching and scholarship

Figure 4: Differing approaches to research inquiry

I want now to focus on *action research* in the context of *pedagogy*: there may be distinctions that should be preserved, but there is also an overlap so far as my purposes are concerned.
So, more on action research:

WHAT IS *ACTION RESEARCH*?

At its simplest, classroom action research relates to any teacher who is concerned with his/her own teaching: to the teacher who is prepared to question his/her own approaches in order to improve the quality of teaching and learning. Hence, the teacher/practitioner is involved in looking at what is actually going on in the classroom [or studio/workshop]. He/she seeks to improve his/her own understanding of a particular problem (or state of affairs) rather than to impose an instant 'solution' upon that unarticulated problem. It is crucial that time be taken for thought and reflection, and it is implicit in the idea of action research that there should be some practical effect of, or end product to, the research which would be based on a now-increased awareness of what actually happens in the classroom. It is, as a consequence, towards the construction of a practitioners' theory, constructed from their experience; and it would intend to be useful.

On this view, some of the characteristics of educational action research are that:

1 its activities and objects are concerned with the deepening of understanding of the studio, workshop, classroom, and school situation by the teacher/researcher adopting a critical, questioning stance. Its starting points are the 'practical problems' experienced by teachers, rather than the problems found within the formal theories of the 'education disciplines'.

2 The presentation of its reporting is in ordinary everyday language, and might well take the form of a case study or story. It adopts the action perspective of practitioners and employs their everyday language to describe and investigate its subject-matter states of affairs.

3 Reflection on experience is part of its processes.

Not all would agree with this, obviously simplified, characterisation of action research, and one of IDATER's functions should be to stimulate discussion about its nature and nuances.

But it's worth noting that such a position justifies and explains the apparent huge diversity of 'low level' inquiries that are pursued by practitioners; the apparent absence of large formal theory (which, from the in-field perspective of some other research tradition, might be described pejoratively as 'no research tradition'). It also makes a distinction between it and the empirical-analytic mode of hypothesis testing paradigm of inquiry - and almost, in some cases, a separation between the two.

It's worth noting several points that begin to emerge:

The borderline between *(action) research* and *development* is not clear cut. Educational practice can contain both research and development. It is not in the tradition of traditional empirical-analytical research: while the traditional empirical researcher hopes not to change the educational structure or process being studied, the hope of the educational action researcher is precisely that of bringing about change. This coupling together of influence, intervention, and effect, which is the trademark of action research, is largely and regrettably repudiated by some traditional empirical researchers.

In traditional empirical research, the researcher's possible influence on the phenomena is viewed as a disturbing variable that must be diminished as much as possible. But educational action research assumes an attitude of consciously attempting to break down the separation (though not the distinctions) between theoreticians and practitioners. The assumption of equality of the implicated parties – that neither of the parties rules over the other – is a basic principle for upholding what the terminology of philosophy calls 'discourse'.

Discourse is a form of dialogue in which the course, or direction, (and not just the content) undergoes argumentative trial. (Brock-Utne, (1980, p13)) The point of discourse is not that it is without course, but that the direction of the course has not already been set. Action researchers are partners in discourse; the ideology is democratic. The resulting concept, that discourse is *a key instrument of analysis in educational action research,* is a fruitful one. It is to do with the skills of linguistic philosophy (as method), as distinct from the philosophy of language (which is a subject).

The widely perceived appropriateness of action research to, first, the practitioner-as-researcher and, second, the 'problems' that are grounded in the experience of practice draws attention to the differences between *educational* and *scientific* research. Many mid-career practitioners working in advanced studies or on inquiries that lead to the award of higher degrees try (initially at least) to employ a methodological approach and a vocabulary popularly associated with notions of how research activity is thought to be pursued in the natural sciences. The commonly understood approach in the natural sciences is thought to be the proper, and the required, research approach. And yet the large majority of practitioners are deeply sceptical towards the results of educational research that is based in the natural sciences approach: the results are frequently regarded as misleading, trivial, reductive, begging the questions, or simply as wrong-headed.

I suspect that a large part of a possible explanation for the mis-match between these researchers' results and their reception by practitioners is indeed in the natural science connection.

Michael Bassey pursued the matters some years ago, exploring distinctions between *scientific research, science, educational research,* and *education* and, then, the consequences. In arriving at a notion of what educational research is, he exposed two 'ought' statements:

> The first is this: all teachers ought to be constantly striving to improve their teaching. This statement raises the questions of what is meant by 'improve'; by what criteria can improvement be judged; and who is competent to make such judgements? I suggest that the only significant replies to these questions are the teacher's own replies: it is his meaning of improvement, his criteria and his judgements, that matter, for it is these which will influence his teaching behaviour. Others may suggest, advise or cajole him, but in the event it is his own judgement which causes change in his teaching.
>
> The second is that educational research ought to be concerned with ways of improving teaching. Since the interpretation of improvement lies with the individual teacher, the function of educational research is to influence the thinking of the teacher; to challenge complacency, to question methods, to encourage self-

> analysis, to suggest alternative approaches, to promote creativeness, to foster self-awareness towards others.
> (1980, p17)

He went on to consider sociological, psychological, philosophical, and historical research about educational situations; and concluded that educational research (never mind educational action research) was different from the two social sciences because it has no useful generalisations, and it was different from all four modes of inquiry because of the value orientation towards improvement. (*ibid*)

All this is supportive towards the validity and propriety of action research, and towards the notion of the practitioner-as-researcher. It supports the position that would attempt to institutionalise the processes of review and development as part of being a practitioner/teacher. It is strongly supportive towards IDATER's position. That the role of the practitioner can readily encompass and institutionalise the functions of careful systematic review and development is nevertheless a minefield: it has its problems. Some of the inhabitants of this minefield maintain that their everyday professional activity is research.

That is not an area or argument we have time to attempt to disentangle now: sufficient simply to note that there is a frequent failure to distinguish between academic research (with its (usually) intended outcome of achieving an academic award) and the systematic inquiry that is part of professional everyday activity; and there is, almost invariably (and most surprisingly), no reference to the epistemological bases in any putative analyses of the distinctions between the two classes. That's a comment on the quality of analyis: more assertion than analysis.

Action research, as characterised and principled here, supports the detailed close-up activities of practitioners who are concerned to reflect upon and develop their specifically contextualised practices and understandings in a systematic and rigorous way rather than to engage in the kind of technical problems that are located in the formal theories of disciplines associated with education. It supports the diversity, the apparent lack of large formal theory, and the shift away from methods of inquiry that are associated with, especially, the natural sciences.

Back now to the framework/map: Figures 2 and 3.

I earlier suggested that this framework can be helpfully useful in showing the gaps in our knowledge; that it can help locate our particular efforts; that it can help make more coherent, and related, disparate efforts. It can alert us to the need to make and retain distinctions (such as those between design in general, professional designing, designerly activity in the curricular activities of general education, the school subject of Design & Technology, other design-related curriculum subjects, design as a dimension - not subject-based or subject-bound - of the curriculum or, well beyond that, of human experience, and so on). It can also help us, therefore, to distinguish the wood from the trees. So far so good. But I want now to look very briefly at a number of areas/dimensions/big topics that, in contrast to the low level of specificity of many practitioners' interests, are perhaps at a fairly high level of abstraction and generality, and thus, apparently, not always easy to connect to everyday practice. But they are in the 'ideas culture' of Design and, unexamined or not, they have effect. But when they are examined, they can have powerful explanatory or illuminative effect. So, here are a handful, somewhat arbitrarily chosen: there are certainly other candidates; the selection of these, rather than others, carries huge assumptions; and, inevitably, there are cartoons of big ideas, and intuitions that require unpacking.

Remember: bear in mind *the closeness, or distance from*, the everyday direct experience of educational practice.

So, in shorthand, four 'big' topics:

The idea of paradigm shift;
Multiple realities, or, a post-modern world;
Design as a capcity of mind; design as a distinct form of knowledge and knowing;
and
Designing as the making of meaning; values and valueing; identity, meaning and values.

Taking each in turn:

1 THE IDEA OF PARADIGM SHIFT

In passing, the notion of paradigm shift is not one that is much in the day-to-day conversation of practising teachers.

The key reading is Thomas Kuhn, *The Structure of Scientific Revolutions,* (2nd edn), London: The University of Chicago Press 1970

The idea of there being paradigms – that is, recognisable and distinguishable communities of practitioners and established practices, together with their traditions and languages - is useful. The idea that paradigms exist in time and can change, or be changed, or fall into dis-use, or come to the ends of their useful lives, is useful. For instance, we could say (of UK schools-based practice) that a former mainstream paradigm that consisted in Handicraft gave ground to Woodwork & Metalwork, which, in turn, were somewhat transformed (if not actually overtaken) by CDT, which, in turn, may be in the process of transformation by the emergence of D&T. Such transformations are a natural event. But they can be difficult to understand and live with – especially, for instance, if the way you see the world, the way you were inducted, almost unaware, into the profession, into the world-view and ways of being a member of a practitioner community is changed by external imperatives or impositions.

A reading of Kuhn can offer insights into the nature and effects of paradigm shift; Kuhn offers the possibility of models that help produce your own models that lead to better understanding of change (and towards a sense of being in-control); a reading reinforces the view that curriculum practices change as an accompaniment of (rather than being a subsequent function of) personal growth and development; that bottom-up participant change is easier for all than imposed top-down change. For curriculum managers, Kuhn offers insights into the nature of innovation and the management of change.

2 MULTIPLE REALITIES: A POSTMODERNIST WORLD

Take your choice of readings. Toffler's, for instance, are popular works, and include *Future Shock* and *Learning for Tomorrow: the Role of the Future in Education*.

But Anderson's work (for example, his *Reality Isn't What It Used to Be: Theatrical Politics, Ready-to-wear Religion, Global Myths, Primitive Chic, and Other Wonders of the Postmodern World*), is a particularly 'good read'; it's also stimulating vis-à-vis practice in the workshop. It's not usual to provide long extracts from a work but, in this case, it's helpful to offer a fair amount of allusive extract in order to provide a sufficient sense of the style and the content:

> … the social construction of reality: how societies created and maintained realities in the past, how postmodern ideas reveal the workings of the reality-creating machinery, how contemporary operators on the political and cultural scene create new realities before our very eyes. (…)
>
> For Westerners, the issues are more accessible in such fields as the sociology of knowledge, cognitive science, and the body of thinking-about-thinking that has come to be known simply as 'criticial theory'.
> The cognitive scientists, a relatively scrutable band of explorers of the brain and mind, are struggling in new ways with the old question that occupied some of the best philosophical minds of past centuries: what is the match between *human* reality – all our history and science and systems of belief – and the objective reality of the cosmos?
>
> The various answers to this question divide the cognitive scientists into two main camps. On one side are the objectivists, who see the human mind as capable of more or less accurately, more or less impersonally, mirroring external nonhuman reality; on the other side, the constructivists hold that what we call the 'real world' is an ever-changing social creation. (…) [The constructivists] say we live in a symbolic world, with a social reality that many people construct together and yet experience as the objective 'real world'. And they also tell us the earth is not a single symbolic world, but rather a vast universe of 'multiple realities', because different groups of people construct different stories, and because different languages embody different ways of experiencing life. So, according to the constructivist view, people may have not only different political opinions and religious beliefs, but different ideas of such basic matters as personal identity, time, and space.

(…) A mere couple of centuries ago, most societies recognized a single official reality and dedicated themselves to destroying its opposition. You could get burned at the stake for suggesting there might be more than one version of reality. Today, in some intellectual circles, you can get into trouble for suggesting there might be only one. There are, to be sure, plenty of people around who would not mind setting the torch to the constructivists and their many allies. Fundamentalists of all kinds would suppress such notions as socially dangerous, because they believe that there is no basis for social order without a fundamental agreement that some things are not just socially true but by God *cosmically* true, true for everybody and for all time.

Unfortunately for the cause of those who seek such an anchor for our wavering systems of value and belief, there is not, in most parts of the contemporary world, much of a consensus about what those truths are – if there are any – and it is rarely possible to enforce conformity in the good old-fashioned inquisitorial way. So, the constructivists and their ilk – and it is a pretty big ilk – are permitted to go more or less freely about their heretical business.

These postmodern thinkers are in one sense revolutionaries, and in another sense conservatives. You can hardly call them stormers of the Bastille, because the Bastille has already been pretty thoroughly stormed. The old epistemology that equated human beliefs with cosmic reality is now a minority report. Ancient and not-so-ancient systems of eternal truth lie in ruins everywhere around us. The mainstream of social reality has shifted. Yet, although this news is out and many people are acting on it, the full import of the change has not quite found its way into public consciousness.

Most of us in the Western world slip and slide around in the territory between the objectivist and constructivist camps, without much of a clear idea of what we think about such matters. Our everyday experience tends to be objectivist, guided by what the philosophers call ‘naïve realism’: we generally assume that the universe is the way we experience it. But if asked to think about it, we turn into constructivists. Sure, we say, it’s all relative; time and space and identity are subjective ideas – everybody knows that.

Well, yes, probably everybody does know that. But we don’t know we know it. We haven’t yet quite figured out how to live with what we know, and we don’t know what a curious piece of knowledge it is.

Few of us realize that to hold a *concept* of relative truth makes us entirely different from people who lived only a few decades ago, and we complacently overlook the evidence that many people living today profoundly hate the view of reality that seems so eminently tolerant and sensible to the Western liberal mind. ((x-xii)

But how does this enjoyable participation in the culture of ideas connect to designing and to design education and to everyday D&T educational practice? It all seems very distant. It is not.

Consider, for instance, how we conceptualise 'design problems' (or those states of affairs that are so tagged in the shorthand of professional life). Have in mind the superb characterisation of 'ill-defined states of affairs' – or design problems – in Rittel's and Webber's 'Wicked Problems' (1974). And then the changing conception, over the past 10-15 years, about what constitutes a 'design problem' in the curriculum of general education – that is, the huge conceptual (and therefore operational) differences that are indicated by the two entirely different questions: 'What is a problem?' v 'When is a problem?' The former refers implicitly to artefacts as ends, and to artefacts as 'solutions' to unarticulated states of affairs. The latter refers to states of affairs, to whose resolution - not solution - artefacts may, or may not, be a legitimate and proper response. The status of artefacts is changed, from ends towards means. New conceptions can be signs of the working out, in and for practice, of 'big ideas'. Different conceptions have huge practical effect and consequence; a model of education that is based on teaching is not the same as a model of education based on learning. Changes in perception and conception can be parented by large and abstract ideas that seem distant from the day-to-day realities of operational curricular practices.

3 DESIGN AS A CAPACITY OF MIND, DESIGN AS A DISTINCT FORM OF KNOWLEDGE AND KNOWING

An essential matter that members of the field ought to be more clear about is the uniqueness or the distinctiveness of the capacity for design: it fundamentalness justifies the existence of design in general education vis-à-vis cognitive and personal development; a range of specialist and distinguishable communities of practitioners; and the significance of design in other contexts (not least that of economic well-being). But sloganeering - 'Design adds value' - is not an adequate making or expression of the case for design. Again, Daley indicated the significance, from various perspectives and in various frameworks, when she wrote:

> … An ability to perceive spatial relationships and to envisage non-existent objects is part of the fundamental conceptual apparatus which makes it possible for human beings to understand the physical world. The relationship between the construing of a comprehensible universe and the perception of objects is, as it happens, one of the critical issues in classical epistemology. Bringing such philosophical arguments together with research in developmental psychology on object concepts seems to offer the beginnings of a true theory of design, by which I mean a theory of how it is possible that we are able to design at all, and not a theory of *how to* design. (*op cit,* p4)

Or, take a more specific and even more unfamiliar focus: that of metaphor. Feinstein comments:

> Metaphor, once regarded solely as an ornamental linguistic device, is now considered to be an essential process and product of thought. The power of metaphor lies in its potential to further our understanding of the meaning of experience, which in turn defines reality. In art and in language, metaphor urges us to look beyond the literal, to generate associations and to tap new, different, or deeper levels of meaning. (…) In this process, attributes of one entity are transferred to another by comparison, by substitution, or as a consequence of interaction.
>
> Langer (1957) contends that metaphor is not only essential to thought, but also that art (visual, performing, literary), as a developed product of thought, is metaphor. That view may provide a basis for arguing that arts education is basic to the cultivation of human intelligence. (…) The symbol-making function is the capability to decide that one thing shall stand for another, a decision which presupposes a transformation.
> … two broad classes of symbolisation, discursive and presentational (or nondiscursive). Discursive symbolization, by definition, necessitates propositional language with a literal meaning.
>
> Langer, however, insists that 'the limits of [propositional] language are not the last limits of experience, and things inaccessible to [such[language … have their own forms of conception [and ways they may be presented]. (1976, p265)
>
> Making sense of experience and its products comes about as we interact with our environment in our attempts to comprehend, construct, and convey literal and metaphoric meaning. The core of those attempts is the fundamental act of symbolic transformation.

So what?

Accepting that cognitive modelling is central and necessary to designing, you would expect to find, in curricular aims and objectives, the intention to enable students to be engaged in such experiences and activities as would enable them to make transformations between 2-d and 3-d representations of reality and, further, to enable them to use the mode of presentation and representation best suited to their purposes and audiences.

There have been some, but not many, explicit attempts to devise exercises and experiences that would indeed enable pupils and students to become more adept and competent in forms of modelling. It remains a major area for the investment of effort by practitioners, supported by cognitive science, linguistics, and philosophy. We might expect to find such efforts central to competence-based learning.

It also draws attention to the need to develop a meta-language of professional discourse, which is beginning. Consider (not just in the UK) the notions of 'the design loop', 'the design line': the linear recipe that, in fact, served to show the absence of understanding of the status of models, the functions of models, the limits and the limitations of models. The absence of a developed meta-language can have damaging effects. For example, it has included the long-running failure to discriminate between the linearity of descriptive natural language (as used in some would-be descriptive models) and the non-linguistic phenomena (of designing, and learning) to which that language refers. It seems obvious - once stated - but no models are identical with the phenomena to which they refer.

4 DESIGNING AS THE MAKING OF MEANING; VALUES AND VALUEING; IDENTITY, MEANING AND VALUES

Anderson (*op cit*) would remain a suggestive read. But in the context of designing, a paper by Frank Carruba remains interesting: 'Designing People-Pleasing Products', along with the work of Maslow, which both he and Anderson make use of.

Get the flavour, then - first from Anderson, and then Carruba:

> ‘To be someone; be someone – one of the deep urges of the human heart; perhaps, if we knew how to reckon such things with finality, the deepest of all. It is a need that becomes more intensely felt – and also more difficult to satisfy – as the course of history carries us all further away from the old realities that structured out identities and life experiences for us. (…) We do not, … , have the choice about whether or not to make choices. The best you can do if you want to avoid choice making is to live your life within a cult or fundamentalist religion or a traditional society and try to persuade yourself that you have not chosen that. Yet obviously we do not have complete freedom, either, to choose who to be and how to feel.
>
> Symbolic aspirations, symbolic needs. Abraham Maslow’s famous catalogue of human needs is top-heavy with cravings that can only be satisfied in the symbolic universe. The pressure to be an individual, to create one’s own identity and experience, is a product of the modern era.’ (*op cit,* p131, p132)

In his paper, ‘Designing People-Pleasing Products’, Frank Carrubba (Executive V-P, Philips Electronics) talks of ‘a new paradigm’. He writes:

> I believe that the traditional approach of striving to improve profitability through more effective product development is extremely important, but not enough. Even focusing on customer satisfaction won’t suffice, so long as it is merely seen as a way to achieve profitability. I advocate the reverse: providing a continuous stream of customer benefits is a company’s bottom-line goal and healthy profitability is the best way to get there and stay there. (…) For ultimate effectiveness, I suggest moving away from the very concept of creating products and profits, and instead focus on creating customer benefit.
>
> The American psychologist Abraham Maslow devised the theory of self-actualization. He sees self-actualization as the ultimate plane of human

> awareness, and achieving it was like climbing a ladder. At the bottom rung or lowest level were such basic needs as food and shelter. Only when individuals were secure in these would they be able to progress to a higher level, such as independence and autonomy, friendship, love and esteem. When, in turn, these had been achieved, Maslow argued, the individual could ascent to the highest level of all, self-actualization. Maslow’s view of the world can also be applied to product development – the creation of relevant objects. By relevant objects, I mean products that will enable the individual to climb the rungs of Maslow’s ladder. These are products that use technology to encourage the individual’s cultural growth, promote the enhancement of the senses and extend the individual’s knowledge.
>
> (…) It is necessary to cease thinking of the product as an end in itself. Rather, it must be a creator and carrier of knowledge, services and emotions. In this shift towards viewing products as carriers of new qualities, design is moving from ‘hard’ to ‘soft’, from quantity to quality, Products no longer convey image, but identity.
> (1993, p4, p5)

This is confirmation of a shift from seeing the artefact as the outcome of D&T activity towards seeing the artefact as a means towards a quite different end: the making of identity, values, and meanings. This is not new to the liberal and generous view of the purposes of education, (but it is remarkably uncommon in the utilitarian-instrumental world-view that is common in Design & Technology). It is possible, however, that work in product semantics could add something to this view of *design as the making of meaning*. But the concerns of product semantics are not actually new either: look outside the design research literature and practices and they’ve been perennial matters of long standing.

There is any number of other ‘big ideas’ that may appear distant from everyday educational practice but which can have dramatic effect on how we practise. We may need a map, or a compass; we certainly need to move beyond the narrow confines of specialist thinking in order to jack up the horizons of Design & Technology and develop the analysis, the theory, the practice, and the curricula of Design. None of these ideas is particularly new; none is difficult; all are easily accessible. The apparent absence of their impact, in general, on the world of Design & Technology may simply mean that ideas, anyway, take a long time to work through a culture.

To summarise what is no more than a number of starting points for further discussion and development, I’ve asserted

1 that we should support the practitioner-as-researcher: it is an aspect of being a teacher/practitioner that can have huge effect on curriculum and on teaching and learning, as well as on professional status;

2 that action research should be supported: it is especially appropriate to being a practitioner;

3 that practitioners can connect the ‘ideas culture’ to ‘ordinary’ practice;

4 that a new paradigm is emerging (or paradigms), signalled by the development of a running professional conversation, and in the emergence of a meta-language of discourse, and, indeed (from another perspective), in confusions; and

5 that IDATER is one instrument (among many) that supports the emergence of the practitioner-as-researcher, the in-field improvement of practice, and the development of (what would be) a practitioners’ theory.

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KEYNOTE ADDRESSES FROM IDATER99 AND IDATER2000

Creating Design Knowledge: From Research into Practice

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1. Introduction
2. Design and evolution: a prehistoric prelude.
3. Defining design
4. What is knowledge?
5. Experiential and reflective knowledge
6. Theory and research
7. What is research?
8. Reasons for research
9. When practice doesn't want research
10. From research into practice

Keywords: design knowledge, research, practice, innovation

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1. Introduction

Design knowledge involves many questions. Some of these questions are the fundamental ontological and epistemological questions that are fundamental to any field. In design, we have only recently begun to ask them.

What is design? What is the nature of design? Does design involve knowledge of certain kinds? How - and why - does design involve knowledge of certain kinds? What are the sources of design knowledge?

Research is one source of knowledge, and research involves questions. How does research function as a source of knowledge? How does research relate to other sources of knowledge? How do we create design knowledge through research? How does new knowledge move from research into practice?

In this paper, I consider these questions. While I will not answer them completely, I will unfold a range of rich ideas, outline issues and answers, offer conceptual maps, and present sources for those who want to go further. (The paper is followed by two endnotes that contain condensed literature reviews. The first covers the subject of knowledge. The second deals with innovation.)

2. Design and evolution: a prehistoric prelude

As professions go, design is relatively young. The practice of design predates professions. In fact, the practice of design – making things to serve a useful goal, making tools – predates the human race. Making tools is one of the attributes that made us human in the first place.

Design, in the most generic sense of the word, began over two and a half million years ago when *homo habilis* manufactured the first tools. Human beings were designing well before we began to walk upright. Four hundred thousand years ago, we began to manufacture of spears. By forty thousand years ago, we had moved up to specialized tools.

Urban design and architecture came along ten thousand years ago in Mesopotamia. Interior architecture and furniture design probably emerged with them. It was another five thousand years before graphic design and typography got their start in Sumeria with the development of cuneiform. After that, things picked up speed.

Today, we have replaced cuneiform with ASCII characters. Instead of chipping rock, we download it with peer-to-peer software such as Napster or Gnutella. We have not yet replaced spears with pruning hooks or swords with ploughshares, but we do provide a far wider range of goods and services than the world has known before.

All goods and services are designed. The urge to design - to consider a situation, imagine a better situation, and act to create that improved situation - goes back to our pre-human ancestors.

Design helped to make us human. It did so in several ways. Among the frequent misunderstandings of evolution theory is the notion that evolution somehow programmed us to become something or to behave in a certain way. This is not quite so, and the subtle distinctions are significant to how we can develop further.

The initial stimuli of evolution were random. Biological life on our planet has existed for billions of years. The many forms of life over those years shaped a rich enough environment to permit hundreds billions of different events, manifestations, behaviors, evolutionary streams. Some of those manifestations gave the creatures manifesting them competitive advantage in local environments. These creatures survived long enough to pass their genes on and their descendents sometimes survived to pass the genes further. When a large enough population pool existed to permit the gene-carrying population to spread, these traits sometimes spread further still into larger environments.

In early biological evolution, all stimuli were random stimuli. Genetic endowment changed through chance. Chance arose through mutation caused by radioactive change to the genetic structure, through other forms of mutation or biological breakdown in a prior genetic structure. The infinitely vast majority of mutations were not successful, and the creatures went extinct. Over the billions of years of life on our planet, most life forms died out.

In a few, rare case, mutations conferred advantage on a specific life form in a specific environment. These advantages were preserved and passed on.

The environment forms the context within which initially random adaptations create successful species. Success in evolutionary development is not purposeful. It simply means that the environment selects a species for survival based on physical and behavioural characteristics. When a mutation proved well suited to the environment, the species survived. The descendants of creatures whose characteristics were defined by beneficial mutations inherited what had once been new genetic matter. The human species and its predecessor species emerged in and adapted to a specific physical world. The physical world to which we adapted defined us.

Complexity theory (Aida *et al* 1985; Casti 1995; Waldrop 1992) offers a rich series of explanations of how adaptation takes place. One of the salient paradigms of complexity theory is the idea that complex adaptive systems shape their behavior within what is known as a "fitness landscape." As complex adaptive systems fit themselves to the landscape, the context itself takes on different shapes and meanings. Complex adaptive systems include all biological creatures: plants, animals, individual humans. They also include the communities or societies that these creatures create. Their evolutionary paths move through time and history. Some vanish, others develop. Either way, there is no going back.

At some point, life forms became sufficiently advanced to capture behavioral adaptation as well as genetic adaptation. Creatures whose behavior conferred evolutionary advantage fared better than other creatures. The interaction between behavior and biology, nature and nurture is complex. A creature survives better because it possesses a larger brain with a richer brain structure. The continually improving brain enables the creature's offspring to do better still. New behaviors make survival more secure. Secure survival preserves the gene pool. And so on.

Tool-making helped us to become what we are. Tool-making probably preceded language behavior. Tool-making therefore preceded conscious imagination, the ability to imagine and to plan, and animals other than humans make tools. At the start, our tool-making ancestor *homo habilis* was not human. *Homo habilis* was one of the advanced animals that made tools.

In evolutionary terms, we developed the modern brain in the relatively recent past. The physical potential of this brain gave rise to our current habits of mind, the habits that support our mental world. The forces that give rise to the modern mind go back over two and a half million years to the unknown moment when *homo habilis* manufactured the first tools (Friedman 1997: 54-55; Ochoa and Corey 1995: 1-8). Our tools and our tool-making behavior helped to make us human.

As tool-making and tool use became the conscious subject of willed imagination, our tools and tool-making behavior helped us to survive and prosper as humans. There is no way to know when or exactly how we began to create conscious mental symbols, and there is no way to know exactly when symbols became our preeminent tool. While we don't know when we began to use language, we do know when we created the first external documentation and information systems. This took place some 20,000 years ago (Burke and Ornstein 1997: pp. 29-30). The externalized representation of knowledge through documentation and information created a new kind of human being. The first, rudimentary information tools took the form of what archeologists call the baton, a carved bone or antler. Even in this primitive form, information tools began to "reshape the way we think" (Burke and Ornstein 1997: 29-31). This was "the first deliberate use of a device which would serve to extend the memory, because with it, knowledge could be held in recorded form outside the brain or the sequence of a ritual." The relationship between these tools and the human mind is significant, in that "the cognitive facilities needed to make the batons required a brain capable of a complex series of visual and temporal concepts, demanding both recall and recognition. These are exactly the same mental abilities which are involved in modern reading and writing."

At this point, and many points like it, the random workings of natural selection were taken over by the complex human phenotype – the properties that are caused by the interaction of genotype and environment. This environment includes the development of culture and all that it entails. Tool-making relates to the many qualities that make us human, and they all relate to tool-making. These issues involve a large range of conceptual tools and symbols.

This may seem to be a long prelude to defining design. There is a reason for it, and it has to do with understanding the nature of the design profession. On the one hand, design helped to make us human. On the other, the act of designing has been so closely linked to human culture that we have not always given it the thought it deserves. From *homo habilis* to baton, product design precedes symbolization by nearly two and a half million years. Ten or twenty thousand years is a sprint in this grand marathon. In this sense, tool-making is more deeply integrated into our behavior and our culture than symbolization.

The Greek philosophers devoted their attention to the relatively new tools of structured thinking rather than to the old physical tools that seemed so self-evident in the world around them. Physical tools are visible everywhere and all the time in the human environment. They are so obvious and evident, that their omnipresence has obscured the importance of design rather than making it clearer. The evident, omnipresent and persistent quality of design has embedded design in everything that humans think and do. For that very reason, design - a conscious profession focused on the design process - has been a long time in development.

Many of the acts of design, especially the physical acts, have been embodied in craft practice and guild tradition (Friedman 1997). These slowly evolved into a distinct practice of design only in the aftermath of the industrial revolution. The move from a practice to a profession has been more recent still. The notion of a design profession is an innovation of the twentieth century. The idea of a design discipline is more recent still. We are still debating whether the arena of design knowledge constitutes a discipline, a field, or a science. My view is that it is all of these in some measure. This debate is also current for another reason. Design entered the university curriculum in most places only during the past half century.

This development has taken different courses in different nations. In North America, for example, design courses began to enter the colleges and universities with art programs. Most of these began in the late 1940s and since. Many - perhaps most - university-level programs with a specific focus on design are innovations of the past two decades, as contrasted to the occasional design courses available in larger and somewhat older art programs. In other nations, design programs grew within and then grew out from architecture schools or technical colleges. In some parts of the world, the design curriculum attained university standing when design programs in schools of design, art or architecture were raised to university-level professional schools by the government. In the United Kingdom, design entered the university when the colleges of art and design that had become polytechnics were merged into the new universities.

These changes were rooted in many kinds of transformation. The new location of design education in the university clarified the nature of design as a professional practice rather than a vocation or a trade. It is significant that design entered the university in a time of economic transition. The years between 1950 and 2000 were the years in which the economy shifted from an industrial economy to a post-industrial economy to an information society and a knowledge economy [See endnote 1]. Contemporary design takes place in this new economy – including the process of shaping artifacts through industrial design and product design. Placing design in the university rendered visible the importance of the design profession as an important service profession in the post-industrial knowledge economy.

At the same time that the development of university-level design programs clarified the importance of the design profession, it began to make the gaps in our understanding of design knowledge visible. The articulate ontology and epistemology that serve as the foundation of other fields did not accompany the emergence of a new professional training.

The first professional schools located in universities were medicine, law, and theology. Admission to these schools presumed a foundation of knowledge developed in the general faculty. The professional faculties were sometimes called the higher faculties, and they were contrasted with the lower faculties in an important sense. The higher faculties trained professionals for the services of medicine, church, and state. The lower faculties provided the basis of understanding and interpretation, reason and knowledge on which society itself was established.

When art and design came into the university, they often came in as art and craft schools or professional schools. The educational foundation they offered was not the basic philosophical foundation offered for admission to the other professional schools. It was often a combination of vocational training and pre-professional education. Even colleges and universities with general education requirements sometimes cut corners in training students for art and design. In university systems that administer professional training from first admission up, there were no corners to cut.

We find ourselves, therefore, in strange territory. On the one hand, design is anchored in a range of trades or vocations or crafts. These have never been defined in philosophical terms because they have had no basis in the work of definition. They are rooted in unspoken assumptions. Their anchor is an inarticulate practice going back beyond prehistoric humanity to our prehuman development.

On the other hand, the design profession is a contemporary field growing within the university. Having few historical roots in the philosophical tradition deeper than the last few decades, we have yet to shape a clear understanding of the nature of design. We do not agree, therefore, on whether design knowledge constitutes a discipline, a field, or a science, one of these, two or even all three. I see design knowledge as all three. The disagreement is evidence of a growing, healthy debate.

3. Defining design

A rich and growing literature in the philosophy of design makes clear that there is no longer an apparently tacit consensus on the undefined nature of design that once seemed to obtain. Instead, this literature has begun to develop a deep concept of design. This concept is being rendered explicit. Explicit conceptualization permits fruitful inquiry and reflection.

To understand the nature of design knowledge, we must define what we mean by the term design. Since there is no common and well understood definition for design, I will offer some definitions and parameters. A clear definition is vital to the issues I will consider in this paper.

Design is first of all a process. The verb design describes a process of thought and planning. This verb takes precedence over all other meanings. The word “design” had a place in the English language by the 1500s. The first written citation of the verb “design” dates from the year 1548. Merriam-Webster (1993: 343) defines the verb design as “to conceive and plan out in the mind; to have as a specific purpose; to devise for a specific function or end.” Related to these is the act of drawing, with an emphasis on the nature of the drawing as a plan or map, as well as “to draw plans for; to create, fashion, execute or construct according to plan.”

Half a century later, the word began to be used as a noun. The first cited use of the noun “design” occurs in 1588. Merriam-Webster (1993: 343) defines the noun, as “a particular purpose held in view by an individual or group; deliberate, purposive planning; a mental project or scheme in which means to an end are laid down.” Here, too, purpose and planning toward desired outcomes are central. Among these are “a preliminary sketch or outline showing the main features of something to be executed; an underlying scheme that governs functioning, developing or unfolding; a plan or protocol for carrying out or accomplishing something; the arrangement of elements or details in a product or work of art." Only at the very end do we find "a decorative pattern." The definitions end with a noun describing a process: "the creative art of executing aesthetic or functional designs."

Although the word design refers to process rather than product, it has become popular shorthand for designed artifacts. This shorthand covers meaningful artifacts as well as the merely fashionable or trendy. I will not use the word design to designate the outcome of the design process. The outcome of the design process may be a product or a service, it may be an artifact or a structure, but the outcome of the design process is not "design."

Using the term design as a verb or a process description noun frames design as a dynamic process (Friedman 1993). This makes clear the ontological status of design as a subject of philosophical inquiry.

Before asking how design can be the subject of inquiry, it is useful to identify some of the salient features of the design process.

Fuller (1969: 319) describes the process in a model of the design science event flow. He divides the process into two steps. The first is a subjective process of search and research. The second is a generalizable process that moves from prototype to practice.

The subjective process of search and research, Fuller outlines a series of steps:

teleology -- > intuition -- > conception -- >
apprehension -- > comprehension -- >
experiment -- > feedback -- >

Under generalization and objective development leading to practice, he lists:

prototyping #1 -- > prototyping #2 -- > prototyping #3 -- >
production design -- > production modification -- > tooling -- >
production -- > distribution -- >
installation -- > maintenance -- > service -- >
reinstallation -- > replacement -- >
removal -- > scrapping -- > recirculation

For Fuller, the design process is a comprehensive sequence leading from teleology to practice and finally to regeneration. This last step, regeneration, creates a new stock of material on which the designer may again act. The specific terms may change for process design or services design. The essential concept remains the same.

A designer is a thinker whose job it is to move from thought to action. A taxonomy of design knowledge domains (Friedman 1992, 2000) describes the frames within which a designer must act. Each domain requires a broad range of skills, knowledge, and awareness. Design involves more skill and knowledge than one designer can provide. Most successful design solutions require several kinds of expertise. It is necessary to use expertise without being expert in each field.

Understanding the issues these domains involve and the relationships between and among them offers a useful framework for considering design knowledge.

Domains of Design Knowledge: a Taxonomy

Domain 1: Skills for Learning and Leading	Domain 2: The Human World	Domain 3: The Artifact	Domain 4: The Environment
Problem Solving	**The Human Being**	**Product Development**	**Natural Environment**
Interaction Method	Human behavior	Methodology	Ecology
Coaching	Information semantics	Market research	Evolution
Mind mapping	Knowledge creation	Innovation research	Environment
Research Skills	Physiology & ergonomics	Problematics	Impact
Analysis	Research & methodology	Product generation	**Built Environment**
Rhetoric	**The Company**	Creating new products	Cityscape
Logic	Organizational management & behavior	Transforming old products	Economy
Mathematics	Business economics	Product regeneration	Social web
Language	Company culture	Correcting problems	Infrastructure
Editing	Leadership	Improving products	Traffic
Writing	Administration	Positioning	Telecommunication
Presentation Skills	Future planning	Re-engineering (lean production)	Airports
Public speaking	Process management	**Design**	Food distribution
Small group	Change management	Product design	Human ecology
Information graphics	Process skills	Ergonomics	**Architecture**
	Company functions	Product semantics	Informated buildings
	Governance	Product graphics	Usage
	Logistics	Functionality	Architecture as idea
	Production	Graphic design	Architecture as corporate identity
	Marketing	Visual ergonomics	Profile architecture
	Finance	Typography	**Interior**
	Society	Corporate design	Furniture
	Trends	Behavioral design	Interior as corporate identity
	Legal issues	Information design	Psychology
	Media	Knowledge design	Function
	Social economics	Process design	Social structure
	Communication	**Manufacturing**	The shape of work
	The World	Technology	The shape of play
	World trade	Operations	The shape of private life
	European Union	Statistical quality control	**Installation**
	USA	Logistics	Philosophy of space
	Asia	Process management	Culture theory
	Cross-culture Issues		Art ideas
	Political economics		Inquiry
	Theory Basics		
	Culture theory		
	Sociology of knowledge		
	Reception theory		
	History of design		
	Sociology of taste		
	Content analysis		
	World history		
	Paradigm analysis		
	Models		

Figure 1 Domains of design knowledge

To work consciously with relationships among the several domains and areas of design knowledge requires systemic thinking. The designer is generally one member of a team or network that works with several issues described by the taxonomy. Here arises a difficulty.

Manufacturing complex industrial products or shaping complex services necessarily involves a large network of interacting systems. When the process works well, nearly every part of the system in some way affects every other part of the system. When parts of the system affect each other adversely, the entire system suffers. This shifts the role of designer from the role of an artist or artisan shaping a specific artifact to the role of a thinker and planner working with a team to realize a product, process, or service. Organization theory suggests building teams or networks to engage the talent for each problem. In today's complex social and industrial environments, the designer works in teams or heads teams.

Systemic thinking gives perspective to the models of design offered here. The designer is neither the entry-point nor pivot of the design process. Each designer is the psychological centre of his or her personal perceptual process. He or she is not the centre of the design process itself. The design process has no centre. It is a network of linked events. Systemic thinking makes the nature of networked events clear. No designer succeeds unless an entire team succeeds in meeting its goals.

Herbert Simon defines design in terms of goals. To design, he writes, is to "[devise] courses of action aimed at changing existing situations into preferred ones" (Simon 1982: 129). Design, properly defined, is the entire process across the full range of domains required for any given outcome.

The nature of design as an integrative discipline places it at the intersection of several large fields (See figure 2). In one dimension, design is a field of thinking and pure research. In another, it is a field of practice and applied research. When applications are used to solve specific problems in a specific setting, it is a field of clinical research.

My model for the field of design is a circle of six fields. A horizon bisects the circle into fields of theoretical study and fields of practice and application.

The triangles represent six general domains of design. Moving clockwise from the left-most triangle, these domains are (1) natural sciences, (2) humanities and liberal arts, (3) social and behavioral sciences, (4) human professions and services, (5) creative and applied arts, and (6) technology and engineering.

Design may involve any or all of these domains, in differing aspect and proportion depending on the nature of the project at hand or the problem to be solved.

The taxonomy of design knowledge and the generic model of design raise implications for design research. These also involve understanding the kinds of knowledge that form a foundation for the research act. This, in turn, will reveal how knowledge moves from research into practice

Before considering design research, I will consider the subject of knowledge.

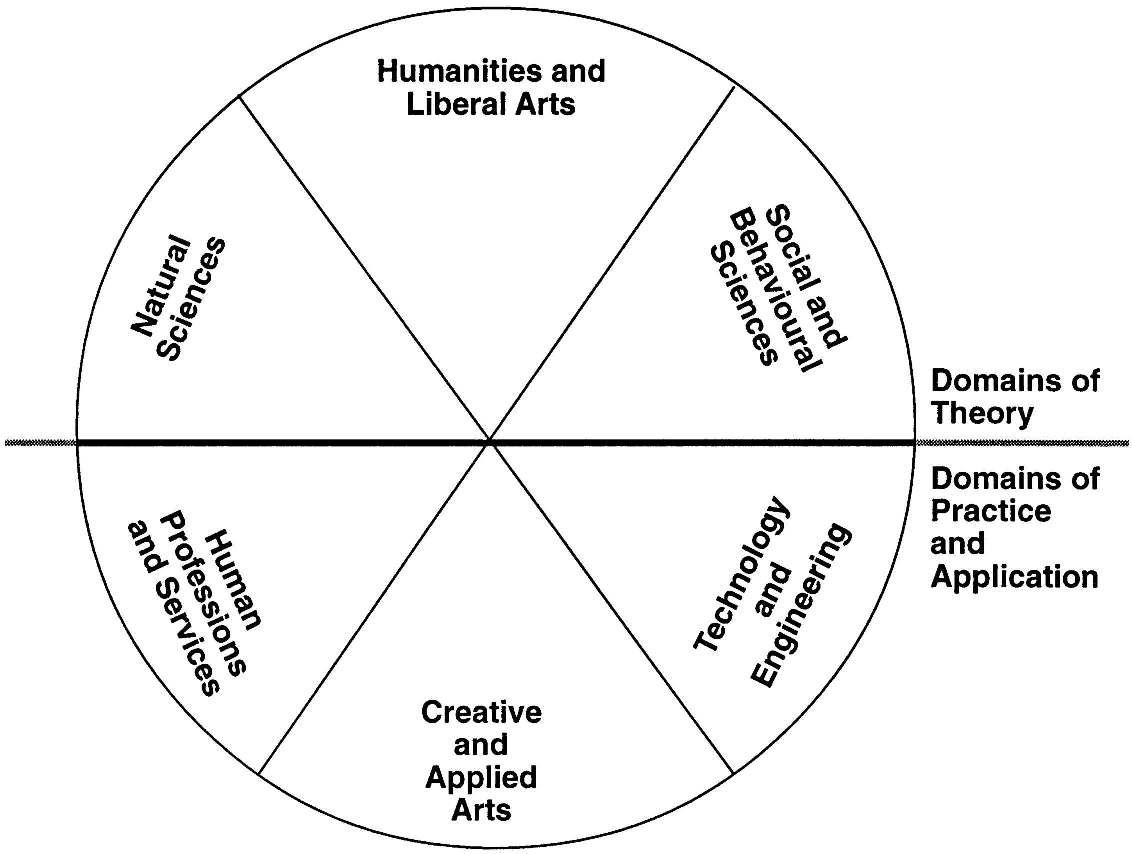

Figure 2 Model of the field of design

4. What is knowledge?

Merriam-Webster defines knowledge as “2 a (1): the fact or condition of knowing something with familiarity gained through experience or association (2) : acquaintance with or understanding of a science, art or technique b (1) : the fact or condition of being aware of something (2) : the range of one’s information or understanding <answered to the best of my knowledge> c : the circumstance or condition of apprehending truth or fact through reasoning : cognition d : the fact or condition of having information or being learned <a man of unusual knowledge> 4 a : the sum of what is known : the body of truth, information and principles acquired by mankind b (archaic) : a branch of learning

"Synonyms: knowledge, learning, erudition, scholarship mean what is or can be known by an individual or by mankind. Knowledge applies to facts or ideas acquired by study, investigation, observation or experience <rich in the knowledge of human nature>. Learning applies to knowledge acquired especially through formal, often advanced, schooling <a book that demonstrated vast learning>. Erudition strongly implies the acquiring of profound, recondite or bookish learning <an erudition unusual even in a scholar>. Scholarship implies the possession of learning characteristic of the advanced scholar in a specialized field of study or investigation <a work of first-rate literary scholarship>" (Merriam-Webster 1993: 647).

Gregory Bateson (1984: 41) once said that "information is any difference that makes a difference." In reality, the power to make a difference defines the difference between information and knowledge. Roger Bacon, the 16th century scholar and a founder of the scientific method, noted this difference in his Religious Meditations, Of Heresies, where he wrote that, "knowledge itself is power" (in Mackay, 1991: 21). Peter Drucker respects that difference, too, and describes the transformation of information into knowledge: "Knowledge is information that changes something or somebody -- either by becoming grounds for action, or by making an individual (or an institution) capable of different and more effective action." (Drucker, 1990: 242)

Knowledge embodies agency and purpose. In this, it differs from information (Friedman and Olaisen 1999b). Information may be stored in information systems. Knowledge is embodied in human beings. Knowledge creation is an intensely human act.

To understand the role of research in knowledge creation, it is ultimately necessary to reflect on what philosophers call "the problem of knowledge." Mario Bunge (1996: 104) states that the problem of knowledge is "actually an entire system of problems. Some of the components of this system are: What is knowledge? What can know: minds, brains, computers, or social groups? Can we know everything, something, or nothing? How does one get to know: from experience, reason, action, a combination of two, or all three, or none of them? What kind of knowledge is best – that is, truest, most comprehensive, deepest, and most reliable and fertile? These five problems constitute the core problematics of epistemology, or the 'theory' if knowledge – which is still to become a theory proper."

These issues are the cores of an entire discipline. This series of problems has much to do with understanding what knowledge is and how knowledge is created. This is a central field of inquiry for a relatively new research field such as design. Bunge (1996) and Alvin I. Goldman (1999) have addressed the problem of knowledge in ways that can be extraordinarily valuable to us. It is vital for us to recognize the importance to our field of the problem of knowledge. Our understanding of design has grown and developed in recent years. Our understanding of knowledge must become richer if we are to apply the problem of knowledge to design. It is through this work that we will develop a proper understanding of what will be required to generate design knowledge.

The definitions of knowledge and design offer a basis for definitional reflections on design knowledge that form a foundation of what follows.

5. Experiential and reflective knowledge

Design is a process. The design process is rooted in and involves both theoretical disciplines and fields of practice. As all fields of practice do, design knowledge involves explicit knowledge and tacit knowledge. Disciplines are also practices, and they, too, involve explicit knowledge and tacit knowledge both. The challenge of any evolving field is to bring tacit knowledge into articulate focus. This creates the ground of shared understanding that builds the field. The continual and conscious struggle for articulation is what distinguishes the work of a research field from the practical work of a profession.

Professional excellence requires articulation. This means rendering tacit knowledge explicit. This is the foundation of what Nonaka and Takeuchi (1995) describe as the knowledge creation cycle. This is also the basis of Schön's concept of reflective practice. Reflective practice is not a form of silent meditation on work. In reflective practice, reflection takes the form of bringing unconscious patterns and tacit understandings to conscious understanding through articulation. This is similar to personal learning and growth in the therapeutic process. It is also related to the way that therapists work with supervisors, to the way that teachers work with master teachers, and to dialogue between professionals in training and their mentors.

Schön (1983, 1990), Argryis and Schön (1992), and Argyris (1961, 1968, 1982) address these issues in their books and articles on professional development through reflective practice and rich learning cycles. This is also the basis of discussion teaching (Christensen, Garvin and Sweet 1991) and case method teaching (Barnes, Christensen and Hansen 1987).

These issues are subtle and require care. All domains of human knowledge embody some form of tacit knowledge. Even the most articulate fields involve assumptions, shared experience, and personal development. All these create a background of tacit knowledge that can never be fully stated. This tacit knowledge forms a central basis for any kind of work.

As Bunge (1996: 104-107) suggests, knowledge arises through the interaction of many forms of learning. Thinking, experience and action all play a role. Although the process of learning and the nature of knowledge are not completely understood, there is wide agreement that knowledge creation requires experience. Kolb's (1984: 38) definition of learning as "the process whereby knowledge is created through the transformation of experience" offers a useful perspective.

Any kind of experience may, in principle, be transformed into knowledge. Kolb emphasizes the relationship between experience and knowledge as a dynamic process of continuous reproduction and regeneration. It contradicts the static model of learning as acquiring knowledge external to and independent of the learner. Information and facts are external to and independent of the learner. Knowledge inheres in human beings and the specific form of knowledge is often contingent on the learning process.

Because knowledge is human, developing knowledge requires thinking and practice, mind and body both. Mindless recording will not transform experience into knowledge. Learning requires human agency, a concept synonymous with Heidegger's concept of care, the human tendency for each person to care about his own existence (Heidegger 1993: 238). For Heidegger, both practical knowledge and theoretical knowledge express of human care in an intimate relationship between doing and knowing.

Human knowledge is not only the product of past experience, but also the product of anticipating the future. Knowing things involves feedforward as well as feedback, anticipating how things may be used, manipulated or acted on in the future. As children, we all discover that anticipatory knowledge – prediction – is not always accurate. Politicians and scientists know this, too. It is part of the knowledge cycle nonetheless.

Kolb's definition of learning fits together with Heidegger's concept of care to suggest a model of individual learning that shifts the focus of learning from the adaptation of external behavior to the internal process of knowledge creation. The model outlines the ways in which human beings monitor and control knowledge through three human capacities. These capacities are 1) the ability to act, 2) the ability to apprehend action and the environment within which action takes place, 3) critical comprehension.

Kolb (1984: 107) writes that, "Comprehension ... guides our choices of experience and directs our attention to those aspects of apprehended experience to be considered relevant. Comprehension is more than a secondary process of representing selected aspects of apprehended reality. The process of critical comprehension is capable of selecting and reshaping apprehended experience in ways that are more powerful and profound. The power of comprehension has led to the discovery of ever new ways of seeing the world, the very connection between mind and physical reality." Critical comprehension is the pivotal force in learning.

This process integrates experience into knowledge through cycles of action and feedback. Knowledge, in turn, supports the human capacity to understand present situations and shape future action. Experience is transformed into knowledge in several ways. One is reflection on the past. The other is the strategic judgment that human agents make as they design the future. These judgments link human beings to the environment by projecting future possibilities in a complex network of cause and effect. Things are understood through their perceived positions in these networks.

The interaction between experience, anticipation, critical comprehension, and knowledge is only part of the story. Situated knowledge also relies on generalized knowledge distinct from – and abstracted from – immediate situations and intentions.

Generalized knowledge guides perception and thus it guides action. It is common knowledge shared among groups of actors. Community among actors depends, in part, on shared common knowledge and the shared nature of general knowledge implies a social process. This social process plays a major role in knowledge creation. While individual actors also create generalized knowledge, every creator of new knowledge builds, in part, on what has come before. Even the greatest individual creators see farther because they stand, as Newton famously put it, “on the shoulders of giants.” Individual knowledge creation is thus a social process.

Two more aspects of human agency drive knowledge creation, habit, and tacit knowledge. Garfinkel’s (1967) experiments demonstrate that a general store of knowledge is essential even to the most mundane activity. This general store of knowledge depends on many factors. These include habituation, tacit knowledge, and the larger social stock of generalized knowledge, together with learning based on experience, anticipation, and critical comprehension.

One fascinating aspect of habitualization is the fact that it plays a role in many different theories of knowledge creation. Berger and Luckman (1971: 70-71) write that, “All human activity is subject to habitualization. Any action that is repeated frequently becomes cast into a pattern, which can then be reproduced with an economy of effort and which ipso facto, is apprehended by its performer as that pattern ... In terms of the meanings bestowed by man upon his activity, habitualization makes it unnecessary for each situation to be defined anew, step by step. A large variety of situations may be subsumed under its predefinitions.”

Habitualization need not prohibit critical comprehension. The two processes work together in dialectical relationship. They are distinct yet related dimensions of learning that depend intimately on each other. One form of habitualization results from repeated acts of critical comprehension that transform experience into knowledge. Critical comprehension depends on a generalized store of knowledge generated by habitualization. The knowledge spiral describes the relationships between these aspects of knowledge.

The knowledge management framework posits knowledge creation as a spiral moving through epistemological and ontological dimensions (Nonaka and Takeuchi 1995: 70-73). The epistemological dimension can be portrayed as a spectrum running from explicit knowledge to tacit knowledge. The ontological dimension describes levels of knowledge moving from individual knowledge through group knowledge, organizational knowledge, and inter-organizational knowledge. One can extend the scale to social and cultural knowledge.

Human beings shift knowledge from one frame to another. As they do so, they embrace knowledge, enlarging it, internalizing it, transmitting it, shifting it, recontextualizing and transforming it. Humans create new knowledge by acting on and working with knowledge. Knowledge creation requires social context and individual contribution. This involves an effort to render tacit or unknown knowledge explicit and known.

6. Theory and research

The difficulty of fitting research into the field of design is not rooted in the nature of design. Neither is it rooted in the nature of design knowledge. The great difficulty arises from a field of practice with a huge population of practitioners who were trained in the old vocational and trade traditions of design. This is to be expected in a profession so new to the university.

This situation is visible in many simple demographic facts. It is reflected in the fact that few university design teachers have had a broad university background. It is reflected in the fact that doctoral programs in design are developing at a pace that far surpasses the availability of trained research faculty. It is reflected in the shortage of design professors and doctoral supervisors who have, themselves, earned a Ph.D. The demographics of design programs reveal many similar problems and challenges. The fact that we recognize these challenges as problems is an important step forward. Diagnosis precedes cure.

These problems are not, however, the fault of craft practice. Quite the contrary. Craft practice is eminently suited to reflective practice. Craft practice is also well suited to theory development and research.

We are now seeing an increasing number of craft practitioners who generate significant research. Some of the work emerging from this field is so significant that it is helping to revolutionize research methods training in other fields. The work of Pirkko Anttila is an important example.

Pirkko Anttila, a professor in craft research, has become a central figure in defining the challenges of research methodology in design. Anttila's (1996) book promises to revolutionize the learning and use of research methods by designers. The book is rooted in a rich, structural approach that assesses design methods in terms of challenges, needs, and desired outcomes. The book enables the individual reader to locate and begin to explore a variety of research concepts through a pedagogically sophisticated program of accessible self-learning. At the same time, the comprehensive overview makes this book a helpful guide to experienced researchers. Researchers in social science, management, and economics as well as in art, craft, and design are using the Finnish edition.

The problems that arise in a population of craft practitioners (Friedman 1997) have to do with educational traditions rather than subject matter. This involves the failure of educators and practices in the arts and crafts – including design – to keep up with the knowledge revolution.

This is a sad paradox. Artisans and shop-floor engineers were leading actors in the industrial revolution. Artisans and artisan engineers helped to develop the foundations of industrial practice. Some played important roles in the birth of new approaches to education and learning. A few - such as bookbinder Michael Faraday or printer Benjamin Franklin - even played a role in the birth of modern science.

The problem we face today is that arts and crafts training - and design training in the art schools - is rooted neither in the rich craft tradition nor in the research tradition of the universities. This gives rise to a culture of people who mistake silence for tacit knowledge and confuses unreflective assertion with reflective practice.

The immature state of the academic discipline and the immature state of the profession in a knowledge economy are two causes of failure in design practice.

Successful design practice requires a rich foundation in experience. Successful design also requires explanatory principles, models, and paradigms. The design profession has developed few of these. Achieving desired change requires a foundation in theory. This demands a conception of preferred situations in comparison with other possible situations and an understanding of the actions that lead from a current situation to a preferred one. General principles are required to predict and measure the outcome of decisions. This is what W. Edwards Deming (1993: 94-118) terms profound knowledge, comprised of “four parts, all related to each other: appreciation for a system; knowledge about variation; theory of knowledge; psychology” (Deming 1993: 96).

The fact that design is young poses challenges to the development of a rich theoretical framework. In order to develop this framework, a community of researchers must identify themselves and enter dialogue. This process has only recently begun. In developing a professional research community, “...discussion about the scope and content of a young field of research helps to form the identity of its scientific community. Internal organization and boundary definitions are central means for the social institutionalization of a specialty. The exchange of opinions and even disputes concerning the nature and limits of a field help to construct identity and thus become bases for social cohesion” (Vakkari 1996: 169).

In this context, “conceptions of the structure and scope of a discipline are social constructs that include certain objects within that domain and exclude others. Depending on the level of articulation, the outline of a discipline dictates what the central objects of inquiry are, how they should be conceptualized, what the most important problems are and how they should be studied. It also suggests what kinds of solutions are fruitful. Although articulation is usually general, it shapes the solutions to specific research projects. This general frame is the toolbox from which researchers pick solutions without necessarily knowing they are doing so” (Vakkari 1996: 169).

The concept of profound knowledge establishes prerequisites for a toolbox of design knowledge that will permit broad understanding linked to predictable results.

Some kinds of design function within well-defined domains such as industrial design, graphic design, and textile design or furniture design. Other forms of design involve several design disciplines and several professions. These include information design, process design, product design, interface design, transportation design, urban design, design leadership and design management.

No single factor determines the location of any given design practice in a specific domain. In today's knowledge economy, therefore, designers must maintain a broad general perspective linked to a range of specific skills in leadership, learning, analysis, knowledge acquisition, research, and problem solving. [See figure 1] The demands of the knowledge economy distinguish mature design professionals from the design assistants who execute specific applications required by the design process.

Intelligent designers are moving beyond craft skill and vocational knowledge to professional knowledge. They do this by integrating specific design knowledge with a larger range of understandings. This includes understanding the human beings whose needs the design process serves. This includes understanding the social, industrial and economic circumstances in which the act of design takes place. This includes understanding the human context in which designed artifacts and processes are used. Intelligent designers also develop general knowledge of industry and business. A broad platform enables designers to focus on problems in a rich, systemic way to achieve desired change.

Research is one source of the knowledge that designers require.

7. What is research?

Britannica Webster's defines research with elegant simplicity. The first definition dates from 1577:

"re·search noun Etymology: Middle French recerche, from recerchier to investigate thoroughly, from Old French, from re- + cerchier to search -- more at SEARCH Date: 1577 1 : careful or diligent search 2 : studious inquiry or examination; especially : investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws 3 : the collecting of information about a particular subject" (Britannica Webster's 1999: unpaged).

The second appears only a few years later:

"2 research Date: 1593 transitive senses 1: to search or investigate exhaustively <research a problem> 2 : to do research for <research a book> intransitive senses : to engage in research" (Britannica Webster's 1999: unpaged).

Design research discussions that label research as a purely retrospective practice have been misleading. Statements that conflate research with positivism are equally misleading. So, too, are essays that proclaim systematic, rigorous research to be inflexible or uncreative. One recent note asked plaintively, "where's the search in research?" as though rigorous research involves little more than tedious cataloguing of established facts. While some aspects of creative research involve tedium, so do some aspects of painting, music, and dance.

It does not require a comprehensive linguistic analysis of the word research to understand that the prefix “re” came to this word from outside English. The prefix does not modify the core word in the direction of past or retroactive conditions, but it emphasizes or strengthens it.

As the dictionaries note (Merriam-Webster’s 1990, 1993: 1002; Britannica Webster’s 1999: unpaged), the meanings of research are closely linked to the senses of search in general, “Middle English cerchen, from Middle French cerchier to go about, survey, search, from Late Latin circare to go about, from Latin circum round about -- more at CIRCUM- Date: 14th century transitive senses 1 : to look into or over carefully or thoroughly in an effort to find or discover something: as a : to examine in seeking something <searched the north field> b : to look through or explore by inspecting possible places of concealment or investigating suspicious circumstances c : to read thoroughly : CHECK; especially : to examine a public record or register for information about <search land titles> d : to examine for articles concealed on the person e : to look at as if to discover or penetrate intention or nature 2 : to uncover, find, or come to know by inquiry or scrutiny -- usually used with out intransitive senses 1 : to look or inquire carefully <searched for the papers> 2 : to make painstaking investigation or examination” (Britannica Webster’s 1999: unpaged).”

Many aspects of design involve search and research together. It is helpful to consider this issue in terms of a triad formed by the concepts of clinical research, basic research, and applied research. This shapes a dynamic milieu closer to the reality of professional practice than the common dyadic division between basic research and applied research. While the dyadic division may suffice for the natural sciences, it is not adequate for understanding research in the technical and social sciences or the professions they support.

Basic research involves a search for general principles. These principles are abstracted and generalized to cover a variety of situations and cases. Basic research generates theory on several levels. This may involve macrolevel theories covering wide areas or fields, midlevel theories covering specific ranges of issues or microlevel theories focused on narrow questions. Truly general principles often have broad application beyond their original field, and their generative nature sometimes gives them surprising predictive power.

Applied research adapts the findings of basic research to classes of problems. It may also involve developing and testing theories for these classes of problems. Applied research tends to be midlevel or microlevel research. At the same time, applied research may develop or generate questions that become the subject of basic research.

Clinical research involves specific cases. Clinical research applies the findings of basic research and applied research to specific situations. It may also generate and test new questions, and it may test the findings of basic and applied research in a clinical situation. Clinical research may also develop or generate questions that become the subject of basic research or applied research.

Any of the three frames of research may generate questions for the other fields. Each may test the theories and findings of other kinds of research. It is important to note that clinical research generally involves specific forms of professional engagement. In the rough and tumble of daily practice, most design practice is restricted to clinical research. There isn't time for anything else.

In today's complex environment, a designer must identify problems, select appropriate goals, and realize solutions. A designer may also assemble and lead a team to realize goals and solutions. Today's designer works on several levels. The designer is an analyst who discovers problems. The designer is a synthesist who helps to solve problems and a generalist who understands the range of talents that must be engaged to realize solutions. The designer is a leader who organizes teams when one range of talents is not enough. Moreover, the designer is a critic whose post-solution analysis ensures that the right problem has been solved.

A designer is a thinker whose job it is to move from thought to action. The designer uses the capacities of mind in an appropriate and empathic way to solve problems for clients. Then, the designer works to meet customer needs, to test the outcomes and to follow through on solutions.

This provides the first benefit of research training for the professional designer. Design practice is inevitably located in a specific, clinical situation. A broad understanding of general principles gives the practicing designer a background of principle and theory on which to draw. This comprehensive background is never used completely in any practical context. Developing a comprehensive background through practice therefore takes years. In contrast, a solid foundation of design knowledge anchored in broad research traditions gives each practitioner the access to the cumulative results of many other minds and the overall experience of a far larger field.

I will consider this issue in discussing how we move from research into practice.

Before asking how research can serve practice, however, it will help to define research in a summary way.

Research is a way of asking questions. All forms of research ask questions, basic, applied, and clinical. The different forms and levels of research ask questions in different ways.

What distinguishes research from reflection? Both involve thinking. Both seek to render the unknown explicit. Reflection, however, develops engaged knowledge from individual and group experience. It is a personal act or a community act, and it is an existential act. Reflection engages the felt, personal world of the individual. It is intimately linked to the process of personal learning (Friedman and Olaisen 1999b; Kolb 1984). Reflection arises from and addresses the experience of the individual.

Research, in contrast, addresses the question itself, as distinct from the personal or communal. The issues and articulations of reflective practice may become the subject of research, for example. This includes forms of participant research or action research by the same people who engaged in the reflection that became the data. Research may also address questions beyond or outside the researcher.

Research asks questions in a systematic way. The systems vary by field and purpose. There are many kinds of research: hermeneutic, naturalistic inquiry, statistical, analytical, mathematical, physical, historical, sociological, ethnographic, ethnological, biological, medical, chemical and many more. They draw on many methods and traditions. Each has its own foundations and values. All involve some form of systematic inquiry, and all involve a formal level of theorizing and inquiry beyond the specific research at hand.

This systemic approach offers a level of robust understanding that becomes one foundation of effective practice. To reach from knowing to doing requires practice. To reach from doing to knowing requires the articulation and critical inquiry that leads a practitioner to reflective insight. W. Edwards Deming's experience in the applied industrial setting and the direct clinical setting confirms the value of theory to practice.

"Experience alone, without theory, teaches management nothing about what to do to improve quality and competitive position, nor how to do it" writes Deming (1986: 19). "If experience alone would be a teacher, then one may well ask why are we in this predicament? Experience will answer a question, and a question comes from theory."

It is not experience, but our interpretation and understanding of experience that leads to knowledge. Knowledge, therefore, emerges from critical inquiry. Systematic or scientific knowledge arises from the theories that allow us to question and learn from the world around us. One of the attributes that distinguish the practice of a profession from the practice of an art is systematic knowledge.

As artists, we serve ourselves or we serve an internalized vision. This internalized vision is essentially a facet of the self. In the professions, we serve others. In exploring the dimensions of design as service, Nelson and Stolterman (2000) distinguish it from art and science both. My view is that art and science each contributes to design. The paradigm of service unites them.

To serve successfully demands an ability to cause change toward desired goals. This, in turn, involves the ability to discern desirable goals and to create predictable – or reasonably predicable – changes to reach them. Science is a tool for this aspect of design. Research is the collection of methods that enable us to use the tool.

8. Reasons for research

There are many reasons for research, basic, applied, and clinical. These include: curiosity; the desire to know something; the desire to know why something is; the desire to know how something works; the need to solve a problem; the desire to serve a client. There are also practical reasons for research. For university faculty, this includes the requirement that we publish. On the surface, this is simply a career requirement. At a deeper level, the research requirement is based on a simple fact. Those who create knowledge through research have a different and richer relationship to their subject field than those who simply teach the knowledge that others create.

Research has always been closely linked with science. Simon’s (1982: 129) definition of the goal of science in general is understanding “things: how they are and how they work.” This is the goal of science in its larger sense of systematic knowledge. This is why some cultures use the term “science” to cover many disciplines or field of inquiry other than natural or social science. In the sense of understanding how things are and how they work, literature, history or theology can also be seen as sciences.

Campbell, Daft, and Hulin (1982: 97-103) outline the basis for successful research. Successful research requires active research practice and lively involvement with colleagues. Successful research is frequently marked by convergence. Ideas, methods, interests, problems, and techniques interact in the work of a researcher. Good research is often intuitive, based on a sense that the time is right for an idea. (This criterion, of course, is more easily seen in hindsight, since research ideas for which the time is not right tend to vanish.) Successful research arises from concepts. It leads to theorizing and theoretical understanding.

Robson (1993: 26) emphasizes the “real world” value of successful research with problems “arising from the field and leading to tangible and useful ideas.” In this, he is correct.

It is equally important to assert the value of free inquiry and basic research. While basic research is not always concerned with immediate results identified in terms of the “real world,” free inquiry and science have their uses. This is even true in service professions such as design. Free inquiry and science are especially useful as a foundation for improvements to practice.

Science – vetenskap, wissenchaft – is systematic, organized inquiry. All domains of theory-based thinking on design constitute some form of science in this larger sense. Scientific method in the restricted sense used for natural science has its uses, too. In the sense that scientific inquiry can contribute to design, it can, indeed match some of the goals of the design discipline. No one has suggested scientific inquiry can meet all the goals of design. Where science in the large sense or scientific method in the narrow sense can be used, however, they should be used.

Design is both a making discipline and an integrated frame of reflection and inquiry. This means, that design inquiry seeks explanations as well as immediate results.

One way to build better artifacts or cause change in a desired direction is to understand larger principles. This requires philosophy and theory of design linked to general explanation. I do not suggest that everyone should pursue this kind of research. Even so, it would be a mistake to restrict design research to the narrow, immediately practical goals most interesting to practitioners. History demonstrates that practitioners are not always well equipped to judge the long-term value that research holds for their profession.

Judged on immediate professional application, there is little evident purpose in much of the most interesting work in design research today. Nevertheless, if design research were restricted to narrow, immediately practical goals deemed acceptable to practitioners, there would have been no purpose in much of the work of several major figures in design, engineering or industrial practice. Some of the figures of whom this is true are W. Edwards Deming, Donald Schön, Buckminster Fuller, Victor Papanek, Henry Petroski, and Edward Tufte.

There are powerful theoretical arguments for research and explanation. The evidence of design research and design practice also supports these ideas.

Explanation is a profound source of better application. While applications lie in the realm of practice, explanation lies in the realm of science. To expand the frame of knowledge within which better applications emerge, we require profound explanations and the freedom to seek them in pure form.

Many design researchers – and some designers – seek to understand the world to explain it. Let us consider why a robust design process requires understanding to explain. To use Simon's (1982: 129) elegant definition, to design is to "[devise] courses of action aimed at changing existing situations into preferred ones." Why would we require an explanatory design science for this to happen? To change existing situation into preferred ones, we must understand the nature of preferred situations and the principles through which we achieve them. This means, in Simon's (1982: 129) words, understanding "things: how they are and how they work."

The best argument for the importance of understanding how things are and how they work is the frequent failure of design outcomes. Unintended consequences and performance failures result most often from a failure to understand how things are, how they work, and – more important – a failure to understand the linkages between designed processes or artifacts and the larger context within they are created and found.

Design activity involves goals other than natural, physical, and social science. It also involves some of the same goals. What is different in design is that the framework of inquiry is both interdisciplinary and integrative. The larger frame of design involves issues that are different from the sciences and it involves issues that are explicitly parallel. Explanation is not our only goal. It is often among our goals. In some forms of design research, it may well be the essential goal of a specific inquiry.

Explanatory power is also the fuel of better practice.

Ideas and projects that do not work mark every growing field of inquiry. Methods, theories, even historical accounts, and interpretative frames begin as proposals. These proposals begin in some form of idea or inquiry or even in some form of intuition or inspiration. The professions, technology, the humanities, social science, and natural science are all littered with obsolete ideas that once seemed promising. These ideas – dead as they are – form a part of the skeleton around which knowledge grows. Dead ideas and obsolete concepts are among the signs of a growing field. We must be free to propose ideas. Once proposed, ideas must be subject to critical inspection, application and perhaps even testing to see which ideas work best.

The logic of idea generation involves intuition and deduction as well as induction and abduction. Kepler got to his laws of planetary motion the long way round. He started by trying to fit the orbits of the planets to models ranging from music scales to a post-Pythagorean model of nested Platonic solids. By testing these against observational data, he eventually developed a series of laws that explain the model of the solar system we have used ever since. This, in turn, led to Newton's work.

The earlier predictions of Ptolemaic astronomy worked perfectly well for the practitioners of the day. While the Copernican model of the solar system was essentially better than the Ptolemaic model, Copernicus relied on an Aristotelian doctrine that uses perfect circles to describe celestial orbits. Since the planetary orbits are not circular, the original Copernican model was less accurate than the Ptolemaic model with its rich catalogue of documented and precise observations. Practitioners found Ptolemaic astronomy far more useful and accurate than Copernican astronomy. The two systems competed for over a century after the publication of Copernicus's Revolutions. Many argued, correctly, that Ptolemaic astronomy was the better system in terms of observational data. Despite its lack of mathematical elegance, it was far superior in predictive power. That made it superior to practicing astronomers and astrologers. (The largest group of practitioners using astronomical observations was astrologers.)

For decades, the Copernican model was a strange theoretical artifact with no practical value. Although the Copernican solar system is essentially the correct model, it was deeply flawed in practical terms.

Einstein's theorizing began with discrepancies in the implications of theory. Maxwell's laws implied a profound problem regarding the invariant nature of the speed of light contrasted against the position of the observer. This is the same problem made clear by the Michelson-Morley experiments, though Einstein began with the Maxwell theory and not with the Michelson-Morley observations.

By taking one or two implications of Maxwell's equations at face value, Einstein reached a stunning new kind of proposal. This proposal took the form of special relativity. Here, Einstein was clear. Theory and hypotheses arise from intuition and the free play of the mind. Theory must then be tested against empirical data. In Einstein's case, theory contradicted what many physics practitioners believed to be common sense.

No one denies the important of practice. I do assert that much research that seems to serve practice in the short term fails to serve the long-term needs of a field. In failing to serve significant long-term needs, research restricted to that which seems practical and applicable in today's terms fails to serve the best interests of practitioners.

One of the reasons universities exist - and one of the values of basic research - is generating vital knowledge beyond the immediate constraints of practice.

9. When practice doesn't want research

There are occasions when practice doesn't want research. Sometimes, it does not matter whether things work. Many of Philippe Starck's artifacts are an example of things that apparently do not need to work to succeed in some way. The lemon squeezer where the juice runs off down the legs and the kettle that burns the hand in the act of pouring are good examples. It is said that Alessi now offers a guarantee that some Starck artifacts will not work. The guarantee of dysfunction is supposedly part of the market appeal. I imagine that the next item out will be a prefilled water kettle, sealed and guaranteed to explode, destroying the stove and injuring the cook in the process.

Practitioners sometimes reject vital streams of research while seeking solutions that do work. One of the best known episodes of this behavior comes from medicine.

In the middle of the 19^{th} century, medical practitioners believed that research into antiseptic practice or bacteria had no practical value.

A brief look at the history of antiseptic treatment explains the case. Semmelweiss, Lister, and Pasteur had rough going. Semmelweiss, incidentally, got his initial ideas as an intuition that he tested with simple, rule-of-thumb procedures that were essentially statistical in nature.

Medical research in that era made progress through incremental advances acceptable to the majority of practitioners. These pioneers made the greatest advance of the era with work that was bitterly resisted by practitioners. Most medical practitioners thought this stream of inquiry had no value. It is nevertheless possible that the medical innovations arising from antiseptic research was the most significant advance of the past two millennia in terms of numbers of lives saved in medical practice and clinical application. While there have been more astonishing innovations and many advances have been more dramatic, no single advance did more for health through preventive care than the introduction of antiseptic medical procedures and pasteurizing food.

Effective design research must be an act of free choice. Each researcher is free to decide what goals his or her research will serve. Some design research ought to serve practice. Not all design research should be required to serve practice.

When a form of research is tied too closely to the practice of any specific era, it is often incapable of creating the new knowledge of the future. This is so almost by definition. Research closely linked to contemporary practice leads to incremental improvements more often than breakthrough. Since we do not know what knowledge may be useful in the future, demanding that we exclusively serve today's perceived needs will not advance a field.

Campbell, Daft, and Hulin (1982: 102) also outlined the reasons that are often associated with unsuccessful research. Several of these reasons involve research done for motives other than genuine curiosity. Research undertaken purely for publication, for money or funding are among these. A research theme forced on a researcher is generally linked to one of these motives. Nothing is deadlier to the spirit of discovery.

Fortunately, the world is filled with curious people. As I see it, any robust research pursued with genuine vigor and the spirit of discovery has value. The immediate values and the long-term values of any given research program change and shift with time.

The research dean at a university once told me that a study of faculty publishing revealed that it takes nearly one thousand hours of work to develop a research article from first conception to final publication. Clearly, it is hard to pay for the work this requires. This leaves curiosity and passion as the most reliable motives for research.

10. From research into practice

This paper has explored the nature of design with reflections on how the nature of design involves certain kinds of knowledge. It has explored the sources of knowledge. It has explored research as a source of knowledge, and considered research in relation to other sources of knowledge. This has taken us a long way. I will now consider two final issues in summary form. The first involves how we create design knowledge through research. The second asks how new knowledge move from research into practice.

Creating design knowledge rests on all the sources considered here. Practical experience is only one of these. Practice alone cannot create new knowledge. Not even reflective practice will generate new knowledge in significant measure.

The interplay of experience, reflection, inquiry, and theorizing generates knowledge. One task of research is examining the ideas that arise from the interplay of these different forms of knowledge. Research then helps to establish those forms of knowledge that offer the greatest potential for further development.

This new knowledge moves into practice in hundreds of ways. The field of innovation studies examines the ways that new ideas are adopted in practice. [See endnote 2].

Here, I offer a brief account of how this knowledge moves from research into practice.

In a new field, the greatest need is to build a body of research – and to train a rich network of researchers and research-oriented practitioners able to use the knowledge won in research as a foundation for practice. Research becomes the foundation of practice in many ways. One is the foundation of concrete results. The other, perhaps even more important, is in the development of critical thinking and good mental habits. These are the reasons that argue for the design science approach to design education (Friedman 1997).

Concrete research results become visible to practitioners in a myriad of ways. Journal results, conferences, corridor talk among colleagues, knowledge transfer in shared projects, Internet discussion groups. The important issue is that a field must grow large enough and rich enough to shape results and circulate them. As this happens, the disciplinary basis of the larger field also grows richer. This leads to a virtuous cycle of basic results that flow up toward applied research and to clinical applications. At every stage, knowledge, experience, and questions move in both directions.

The goal is a full knowledge creation cycle that builds the field and all that practice in it. Practice tends to embody knowledge. Research tends to articulate knowledge. The knowledge creation cycle generates new knowledge through theorizing and reflection both.

I'm going to end by proposing the kinds of research that we need to build our field and the kinds of research that we must undertake to build the discipline that supports the field we build.

Not long ago, Tore Kristensen (1999: unpaged) raised an issue of stunning importance for design research in addressing the notion of a progressive research program. This concept is so evident to those of us who work in other fields that we had somehow overlooked the fact that no similar notion had yet been proposed in the field of design.

What is a progressive research program? Drawing on Kristensen (1999: unpaged), I have identified eight characteristics of a progressive research program. These are:

1. building a body of generalized knowledge,
2. improving problem solving capacity,
3. generalizing knowledge into new areas,
4. identifying value creation and cost effects,
5. explaining differences in design strategies and their risks or benefits,
6. learning on the individual level,
7. collective learning,
8. meta-learning.

Four areas of design research must be considered in creating the foundation of progressive research programs within and across the fields of design

1. Philosophy and theory of design
2. Research methods and research practices
3. Design education
4. Design practice.

Each field of concern involves a range of concerns.

Philosophy and theory of design	Research methods and research practices	Design education	Design practice
Philosophy of design Ontology of design Epistemology of design Philosophy of design science Theory construction Knowledge creation	**Research methods** Research issues exploration Progressive research programs Development from research to practice	**Philosophy of design education** Education based on research Education oriented to practice **Rethinking undergraduate education** Undergraduate focus on intellectual skills for knowledge economy Undergraduate focus on practice skills for professional training Undergraduate focus on foundations for professional development **Rethinking professional degrees** Professional degrees oriented around intellectual skills Professional degrees oriented around practical skills Professional degrees oriented around professional development **Research education** Undergraduate and professional background for research education Research master's degrees Doctoral education Postgraduate training **Continuing education** Lifelong learning Partnership with design firms Partnership with professional associations Partnership with industry Partnership with govt	**Comprehensive practice** **Profound knowledge** **Practice linked to solid foundations in education and research** **Professional develop-ment lifelong learning**

Figure 3 A progressive research programme for design

In 1900, David Hilbert gave a famous speech outlining a progressive research program for mathematical knowledge. In the years after Hilbert proposed his progressive research program, mathematicians solved fundamental theoretical and philosophical problems. They contributed to rich developments in physics and the natural sciences. They even shaped applications that make it possible for all of us to live a better daily life. What I hope for in design research is many streams of work leading to new and important kinds of knowledge.

These will serve the field of practice in many ways. Research serves the field through generating direct, concrete applications. Research serves the field by solving problems that arise from the field itself. Research serves the field by considering basic questions and issues that will help to shape disciplinary inquiry and fields of practice both. Research serves the field by opening inquiry into basic questions that we haven't yet begun to ask.

All of these are part of the knowledge creation cycle. The important moment has come in which research joins practice to build a community of design inquiry suited to the challenges and demands of a knowledge economy.

Acknowledgements

I am indebted to Prof. Johan Olaisen for some of the ideas that appear in section 5, "Experiential and reflective knowledge." Several paragraphs appeared earlier in the first chapter (Friedman and Olaisen 1999b: 16-19) of our book, Underveis til Fremtiden.

I am indebted to Prof. Richard Buchanan of Carnegie Mellon University for introducing the useful distinction among clinical research, basic research, and applied research to our field.

Endnotes

(1)

A consideration of design knowledge is not the forum for a detailed discussion of these issues. Nevertheless, design knowledge must be considered against the background of the large cultural, social and economic trends these issues define. Those who wish a richer picture of my views on the social and cultural transformations of the past century will find a deeper discussion elsewhere (Friedman 1998; Friedman and Olaisen 1999a). Those who wish to go deeper still will find a massive body of books and articles. Among these, a few stand out, framing the issues of the new society in a comprehensive philosophical, scientific or socioeconomic frame (eg, Bell 1976; Berg et al. 2000; Borgmann 1984, 1992; Castells 1996a, 1996b, 1996c; Castells and Hall 1994; Drucker 1990, 1998; Flichy 1991, 1995; Innis 1950, 1951, 1995a, 1995b; Machlup 1962, 1979, 1983; Mitchell 1995; Nye and Owens 1996; Olaisen et al. 1996; Paik 1974; Sassen 1991, 1996)

(2)

Innovation studies comprise a broad field of inquiry (Damanpour 1991). Authors distinguish between the “diffusion” and “adoption” of innovations (Kimberly 1981: 85) as well as between studies of “innovating” and “innovativeness” (Van de Ven and Rogers 1988: 636). The primary purpose of most innovation studies has been to demonstrate the existence of empirically distinguishable dimensions of innovation and identify their associated determinants (Damanpour 1991).

Much of the work on innovation has been in the context of organization theory. Given the fact that design is generally an organizational process, these studies can readily be adapted to understand how design research can lead to improved practice in the context of design firms and the industries they serve. While some innovation studies examine organizations well beyond the scope or scale of most design firms, the ideas they develop can be fruitfully pursed in the context of design.

The propensity to innovate is a stable characteristic of organizations over time (Miles and Snow 1978; Miller and Friesen 1982; Mintzberg 1973). It depends on organizational size, structure and leadership (Burns and Stalker 1966; Daft 1982; Damanpour 1992; Damanpour and Evan 1984; Hage and Dewar 1973; Kimberly and Evanisko 1981; Lawrence and Lorsh 1967; Mohr 1969; Tushman and Romanelli 1985; Wilson 1966).

There are several kinds of innovation. These include technological innovation and administrative innovation (Daft 1978; Kimberly and Evanisko 1981; Damanpour 1987). Administrative and technical innovations do not relate to the same predictor variables (Aiken, Bacharach and French 1981; Evan and Black 1967; Kimberly and Evanisko 1981). In the “dual-core-model” of organizational innovation, low professionalism, high formalization, and high centralization facilitate administrative innovation. Inverse conditions facilitate technical innovation (Daft 1978: 206). The “ambidextrous model” of innovation suggests that high structural complexity, low formalization, and low centralization facilitate the initiation of innovations while inverse conditions facilitates their implementation (Duncan 1976: 179).

There are a number of distinctions to be made concerning the quality and character of innovation. Innovation can be either radical or incremental (Dewar and Dutton 1986; Ettlie, Bridges, and O’Keefe 1984; Nord and Tucker 1987). In addition, there are important differences the govern the initiation and implementation stages of adopting of innovation (Marino 1982; Zmud 1982). There are also different organizational levels involved in innovation (Aiken, Bacharach, and French 1981).

Some investigators have found that substandard performance causes dysfunctional behavior and diminished innovation (Caldwell and O’Reilly 1982; Cameron, Kim and Whetten 1987; Hall 1976; Manns and March 1978; McKinley 1987; Smart and Vertinsky 1977; Starbuck, Greve and Hedberg 1978; Staw, Sanadelands and Dutton 1981).

Others argue that poor performance is actually necessary as a catalyst of the search for new practices in an organization (Argyris and Schon 1978; Bowman 1982; Chandler 1962; Cyert and March 1963; Meyer 1982; McKinley 1987; Singh 1986; Wilson 1966;).

Organizations tend to act inconsistently. They can lead their industries with innovative practices in one period, while lagging behind their peers as late-adopters at other times (Mansfield 1968).

An alternative view claims that the propensity to innovate will vary over time, following a company's performance level (Bolton 1993; Mansfield 1968).

A growing body of literature (Tushman and Romanelli 1985; Tushman and Anderson 1986) suggests that organizations evolve through convergent periods punctuated by reorientation or major innovations which reconfigure the organization's path into the next lengthy period of incremental adaptation and adjustment (Miller and Friesen 1984).

Contingency theorists and strategy researchers also provide affirmative theoretical supportive for a positive relationship between substandard organizational performance and innovation. One stream of contingency research asserts that changing environments may lead to declining performance if prompt realignment of the fit between strategy and structure fails to occur (Burns and Stalker 1966; Chandler 1962; Lawrence and Lorsch 1969). Firms experiencing declining performance may therefore change strategies (Miles and Cameron 1982) and ultimately develop organizational structures to respond more effectively to new environmental contingencies. Indeed, one might argue that the increase in "hybrid" organizations, strategic alliances and other novel cooperative arrangements between firms (Borys and Jemison 1989; Powell 1987) constitutes widespread organizational innovation in response to declining performance stemming from environmental change.

There is now a growing body of overview literature in the field, including conceptual articles and reviews Daft 1982; Damanpour 1988; : Kimberly 1981; Tornatzky and Klein 1982; Van de Ven 1986; Wolfe 1994.

Together with two colleagues (Friedman, Djupvik and Blindheim 1995) I reviewed these issues at greater length in relation to professional education and in relation to the specific issues involved in innovation as a research field.

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As if Democracy Mattered… Design, Technology and Citizenship or 'Living with the Temperamental Elephant'

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This presentation takes as its basis the proposals for 'civics and citizenship education' – exemplified from Australia 'Whereas the people: civics and citizenship education' (1994) and from England and Wales 'Education for citizenship and the teaching of democracy in schools' (1998).

Not only is the current orthodoxy impaired – that the content of these reports ought to be the remit of curriculum areas such as Studies of Society – but also the reports' attention to technology is impaired by limited understandings of information and communications technologies. It will be argued that Design and Technology has an obvious and significant role to play in citizenship education and education for democracy. Furthermore, the case is presented that Design and Technology can only claim its legitimate place in a democratic curriculum if it is constructed holistically rather than being limited to the instrumental, the gendered or the vocational.

In addressing the dysfunction between the rhetoric of the reports and the potential of Design and Technology Education to empower students as citizens, workers and individuals, the paper explores:

- the significance of design as a change agent and creator of the future;
- understandings of matters of our very being and existence, and relationships with gene technologies and 'machine consciousness';
- technologies and technological practices which inhibit democracy.

Keywords: education for citizenship, democracy, design and technology

1 Preface

From my personal perspective I'm sharing today some concerns and arguments on topics that I think matter. They matter to educators, they matter to the recipients of education and they matter to the quality of democratic life. This paper is a part of my own ongoing journey with Design and Technology Education, and its genesis came from four factors.

First, in this very room, a year ago to the date, if not the day, we were given food for thought by Sir William Stubbs. There was a suggestion that Design and Technology might contemplate less of a future in the crowded curriculum and there was concern that we ought to make way for other initiatives.

Second, in the context of his remarks and the (then) recently produced draft Crick report on Citizenship I found myself in conversation with some colleagues a day or two later discussing the relationship between such a report on citizenship and Design and Technology.

Third, I was aware of discourse in Australia about Civics and Citizenship Education yet, there too, I knew of no explicit articulation of such concepts through Technology Education. I decided to look further.

Fourth, being an ardent supporter of Design and Technology Education for all students throughout the years of their general education, I take the position that if, in a society which calls itself democratic, Design and Technology Education should be compulsory then, reasonably, it should be constructed democratically. Clearly a small debate looms here, but insofar as my personal journey is concerned, having visited the ethical dimension of Technology Education (Keirl, 1998), something of the notion of 'technological literacy' (Keirl, 1999b), and explored the orthodoxies and potential of the Technology Education curriculum (Keirl, 1999a), it seemed appropriate to critique this curiously fashionable 'Civics and Citizenship'.

2 Introduction

In this paper my core concern is that, despite the staggering influences (overt and covert) of technologies in our lives, we offer a most inadequate education for our co-existence with them. I contend that we seem to miss the educational significance of design as an empowering concept for life in democratic society.

Although I'd been told about it, Richard Sclove's (1995) text Democracy and Technology was not in my hands when I drafted the title to the paper, I assure you! However, it was a blend of serendipity, satisfaction and mild embarrassment to find that he too embraces the phrase that prefaces the title I've given this presentation… 'as if democracy mattered'.

Sclove's text is, I believe, most valuable for our field. It does not deal with education per se but its analysis of design, technology and democracy is significant. He highlights the paradox of the utter pervasiveness of technologies in our lives alongside the utterly inadequate critiquing of those very technologies. I salute his work and have drawn the subtitle for this paper from the following extract. He argues that:

> This complicity in technological decisions that haphazardly uproot established ways of life is as perplexing as discovering a family that shared its home with a temperamental elephant, and yet never discussed - somehow did not even notice - the beast's pervasive influence on every facet of their lives. It is even as though everyone in a nation were to gather together nightly in their dreams - assemble solemnly in a glistening moonlit glade - and there debate and ratify a new constitution. Awakening afterward with no memory of what had passed, they nonetheless mysteriously comply with the nocturnally revolutionized document in its every word and letter. Such a world, in which unconscious collective actions govern waking reality, is the world that now exists. It is the modern technological world that we have all helped create.
>
> (Sclove 1995:5)

Of which, more anon.

I'd like to set out some background and commentary on civics and citizenship and offer some brief notes on democracy. I will then examine a range of ways our field can be viewed to illustrate both its complexity and its educational potential. I contend that so long as we ignore this complexity – or, as I prefer, its richness – then we fail to fulfil our potential. Essentially, narrow constructs serve narrow agendas. I believe that rich manifestations of a Design and Technology curriculum will better reflect and serve rich democratic practice. I draw the paper to a close with some discussion of curriculum issues and pathways we might explore.

3 The movement for Civics and Citizenship

In this country the Advisory Group on Citizenship (AGC) chaired by Professor Bernard Crick published its report 'Education for citizenship and the teaching of democracy in schools' in September last year (AGC, 1998). In Australia, the Civics Expert Groups (CEG) (MacIntyre, 1994) produced their report 'Whereas the people, civics and citizenship education' in 1994. I offer a rather selective summary of each.

Crick offers a three-pronged articulation of 'effective education for citizenship' (AGC, 1998:11):

- social and moral responsibility
- community involvement; and
- political literacy

and these are matched in the Australian approach. Both are proposed as mandatory curriculum components. The AGC argue for 5% of curriculum time and the CEG '... put the view that education for citizenship ranks with English and mathematics as a priority for school education and that it is an essential component of a liberal education.' (MacIntyre 1994:13)

Both reports argue for a thinking citizenry, knowledgeable of rights and responsibilities, able to play a full role in 'participatory democracy', committed to justice, rational behaviour and life in harmony with others. All of which sounds fine and, superficially, teachers and the public alike might find the intentions laudable. However, critiques of what is on offer are illuminating.

The fact that both countries identify alienation, apathy and cynicism as concerns for their participatory democracies leads them to devise strategies for more 'participation'. Thus we find emphasis on educating for duties and obligations in clear preference to the reciprocal of these, namely, rights. The subtly presented picture is very much of the individual and their responsibility to the community - a logical extension being, if you will, the individual's debt to the state. I am not convinced that this is the best way to approach apathy or alienation particularly in our young people!

Furthermore, from the student's perspective, there is little talk of empowerment to action within a democracy. The Australian curriculum materials are weighted by historical analyses while the recommendations for Key Stages 3 & 4 in England and Wales call for assessment based on political language and structures. Talk of basic skills tests in citizenship and 'Certificates of Citizenship' as awards may well keep the portfolio full but must have limited efficacy in empowering students to engage with the social and global issues relentlessly portrayed for them through the media.

Let me draw briefly on a critique assembled by two of my colleagues in South Australia (Gill & Reid, 1999). They see things rather differently. In interrogating why civics and citizenship is being turned onto schools so trenchantly they argue that such moves must be understood in a framework of relations between state, capital and education. They identify a curriculum shift from the 'whole child' to one of 'narrow individualism' and the economy. According to Gill and Reid:

> The citizen is now constructed in narrowly economic terms as a rational and self-interested individual/consumer seeking to maximise her or his personal economic utility, and in so doing serve the needs of an internationally competitive economy… In this post-Keynesian settlement, even the public sector - including the education system - is seen to be producing commodities for discerning individual consumers, rather than working for a common public good.
>
> (Gill & Reid, 1999:62)

These authors contend that governments are opting for a 'minimal', rather than a 'maximal' approach to citizenship education. They cite Evans:

> ‘Minimal interpretations emphasise civil and legal status, rights and responsibilities, arising from membership of a community or society. The good citizen is law-abiding, public-spirited, exercises political involvement through voting for representatives. Citizenship is gained when civil and legal status is granted. Maximal interpretations, by contrast, entail consciousness of self as a member of a shared democratic culture, emphasise participatory approaches to political involvement and consider ways in which social disadvantage undermine citizenship by denying people full participation in society in any significant sense.’ (Evans, quoted in Wyn, 1995, p49).
>
> (Gill & Reid, 1999:63)

This leads me to a couple of points on the issue of political literacy. As I shall show in a moment, there are parallels with Design and Technology education. As with any literacy, there are contested understandings of exactly what is meant by the term. The crudest of constructions are instrumental or operational - for example, that competence in spelling and grammar are enough to constitute a literate student. Knowing language is not enough, it is through language that hermeneutic/interpretive/meaning-making constructions can occur. Further still, being able to reflect <u>on</u> language and make decisions about its very use - by self and others - (critiquing, debating, analysing, and so on) is what emancipates the individual to operate as an autonomous literate person.

So it must be with political literacy. Knowing the terms and the political structures is one thing. Using those basics to create new meanings and understandings and to, ideally, reach a level of critical autonomy as a member of society is quite something else.

Perhaps we should look to the person who holds the pen that creates the term 'political literacy' and ascertain their intentions!

Before moving on, a couple of contextual remarks and a critique of the reports from a Design and Technology point of view will be helpful. Regarding key terms - and I have not pursued an extensive analysis of the reports from either political or philosophical perspectives - I am aware that one social commentator is willing to offer five constructs of 'citizen' (Cox, 1999) and 'democracy', of course, has kept many a pub bore talking to themselves for decades.

As I move nearer to our core business as Design and Technology educators I share two plain objections to both of these Citizenship initiatives. I doubt if either will surprise you. First, neither Design and Technology, nor Technology, in its holistic sense, is mentioned. Information Technology is of course in there, as is mention of 'rapid technological change', sustainable development and future studies. This merely exemplifies the great Catch 22 of our field - until there are properly educated people, that is, with a good Design and Technology education, making informed curriculum decisions about our field, we will have to keep arguing and articulating our case most vigorously.

Second, it is proposed that Citizenship education is to be well and truly centred in the realms of Personal and Social Education or Social Studies. Other subjects are cited - English! Geography! History! In one report Maths and IT are seen with a role of statistical analysis. Design and Technology is (are) almost non-existent.

In the England and Wales document we get a bit of a mention that is possibly less helpful than no mention at all: 'Science and Technology [sic] subjects commonly raise ethical issues of social policy' (AGC, 1998:53). This is the partiality of thinking that we must continue to challenge and overcome for quite some time yet. The species is where it is through thought, language and technology, and it is these three which will articulate our future - whatever its quality - yet we still don't offer a solid education in at least two of them!

4 On Democracy

I turn now to 'democracy' and democracy for the purposes of this paper. I choose to start with Singer, a moral philosopher, whose text How are we to live: Ethics in an age of self-interest? (1993) provides an excellent discourse on the question he poses. His argument that 'ethics is practical or it is not really ethical' is indicative of an approach one might take towards democracy. It seems to me that 'democracy', 'ethics', 'education', 'curriculum', 'design' and 'technology' all have in common that they are contested, dynamic, culturally determined and above all should be practical. Of course, the very fact that they are contested doesn't necessarily help their practicality but it is when attempts to determine them by 'rules' or 'definitions' applied universally and inflexibly that tensions and frictions arise.

Tolerance is a key for our societies today. We know we can co-exist with different value systems and moral frameworks. We seek to extend as much freedom as possible to others and we seek to be free to determine our own pathways and lives. We also value justice and a capacity to be rational to articulate our, and interrogate others', positions and points of view.

Now these dispositions don't just happen and education has a powerful part to play in their adoption by young people. Indeed as White argued so clearly some years ago:

> There is at least one policy which must be in the public interest in a democracy. This is an appropriate education for a democracy.
>
> (White 1973:237)

But what of alienation and cynicism? Is it not reasonable to portray democracy as now deflated, impotent, even fossilised? While it may seem idealistic to pursue 'democracy' as a living entity I am actually comfortable with such a position. If the ideal is, by definition, unobtainable then it must be an appropriate term for democracy as I construe it. With the complexity of its competing variables it must become passive and vulnerable if it loses its dynamism. Regardless of whether complacency or neglect cause stagnation, criticism and contestation must be constituents of democratic society. It is amusing to learn that the Australian citizenship curriculum kit is called 'Discovering Democracy'. It may just be that the view is that democracy is now a fossil awaiting discovery! To the cynic, to those invited to apathy, Singer offers a solution countering 'narrow self interest' and the pursuit of greater goals which can give meaning to our lives (Singer, 1997:30).

5 How might we look at Design, and at Technology, in the context of this discussion?

I'd like now to offer a series of sketches of our field – ways of appreciating its richness and, perhaps, its potential. It will be clear that these sketches are far from universally seen by those beyond Design and Technology Education.

5.1 Orthodoxies of Technology

I have alluded to the dynamic, shifting and contested nature of both 'Design' and 'Technology' and if we are serious about reconstructing the field as values-rich and with ethical purpose then I would argue that this should occur within a framework which views both as cultural practice. While exploring the field of Technology curriculum (Keirl, 1999a) I chose to identify seven 'orthodoxies' with which we must wrestle. I call them orthodoxies in their sense of being 'currently accepted opinions'. (I have been tempted to call them 'orthodoxies of ignorance' but perhaps this is premature or even unkind.) In seeking to strengthen and articulate our field I believe we must challenge these although, with one or two cases, I'm sure you'll want to disagree with me. These are the seven:

- The orthodoxy of technology as 'new'.
- The orthodoxy of technology as 'things'.

- The orthodoxy of technology as ‘neutral’.
- The orthodoxy of technology as 'hi-tech/I-tech'.
- The orthodoxy of technology as 'applied science'.
- The orthodoxy of technology as ‘inevitable’.
- The orthodoxy of technology as ‘incomprehensible’.

The last two are of particular interest to me today. The 'inevitable' facilitates modernist notions of 'progress' despite the fact that there are increasing calls to critique the very 'progress' which we seem to be making (at least in terms of quality of life). Linked with this are notions of 'keeping up' and 'not being left behind' - whether we are talking about a single student learning to use a computer or one national economy trying to stay ahead of others. Teachers and curriculum planners alike are also driven by this notion and try to design curricula to match perceived industrial and business developments and innovations. Given the current rate of technological change and the gap between industry-driven developments and curriculum innovation, I liken this to running after the plane as it heads off down the runway.

It is also here that ‘technological determinism’ and questions of free will arise. Questions of our capacity to choose and control (rather than be controlled by) the technologies we use, are key democratic questions yet the determinist position seeks to negate such choice.

It is partly the seeming impossibility of exercising our will (individual or collective) which contributes to the last orthodoxy - technology as 'incomprehensible'. We may wish, for the sake of expediency, or pragmatics, to confine ourselves to the creation of products and systems, to restrict our understandings and operations to the workshop, studio or notions of applied science. I consider this indefensible for a democratic curriculum. There are key issues here about the philosophy of our field. As you start to construct your personal 'it's all too hard' or 'that's not our brief' arguments in response, let's not mix the philosophical with the political, the educational with the resourcing. I contend that we must seek to articulate the significance of our field for education, for society and for global futures.

5.2 …the Third Culture

We have known and valued for some time the conceptualisation of our field as a Third Culture (articulated by Archer, see Down 1985 and RCA 1979). This articulates what I believe to be a powerful educational case using an appropriate (Design and Technology) metaphor, of 'bridging' the 'gulf of initial incomprehension' perceived by Snow half a century ago (Snow, 1993:4). Berlin (1979:111) is less comfortable with the sense of ‘cultures’ but nevertheless identifies significant epistemological issues for Sciences and the Humanities. Contexts of knowledge, thought, creativity, society and culture are the very fields in which lie our debates today and it has been good to see the ‘Invitation’ in the Conference Handbook[2]. These debates must continue to be pursued with rigour and

[2] The ‘Invitation’ paper from the *IDATER 99 Pre-Conference Handbook* (1999:22-26, Department of Design and Technology, Loughborough University) is reprinted earlier in this book.

the issues clarified if Design and Technology is to a confident and significant component of a democratic education.

We know, for example, that technology can no longer be constructed in the logical-positivist paradigm of science. The values implicit at every stage of intention, manifestation and use of a designed technology are extensive and have consequences. Sclove points out, however, that '...critiques of instrumental rationality, (per se) have no obvious implications for technological design or practice' (Sclove, 1995:102). His position is not one of 'get technology out of politics' but rather 'get democracy into technology'. Thus, I return to the sense of technology as cultural practice.

5.3 ...seeing the Elephant

As with Singer, a core thesis of Sclove's is that we, first, consider the kind of society and quality of life we wish to have and, second, use those considerations to critique the technologies we choose to live with. He points out that we seem willing to accept, uncritically, life with the temperamental elephant. He illustrates his case by pointing to what he calls the 'polypotency' ('being potent in many ways' - rather than omnipotence, 'being potent in all ways') of technologies. Thus he talks of their '… superfluous efficacy … in their functions, effects and meanings.' (Sclove 1995:20) Here, Sclove is suggesting that it is not just the explicit, immediate and functional potency of technologies with which we should be concerned but, further, with any technology's latent and pervasive potency that extends in multiple ways beyond the immediate and the tangible.

Sclove discusses people's tendency to be blind to the social origins of technology and to their social effects. He identifies the dual myths of technologies as 'autonomous self-contained phenomena' and of technologies as 'morally neutral'. He argues that:

> These dual misperceptions concerning technologies actually enhance their relative structural significance, because they enable technologies to exert their influence with only limited social awareness of how, or even that, they are doing so. This helps explain why people are prone to resign themselves to social circumstances established through technological artifice and practices that they might well reject if the same results were proposed through a formal political process.
>
> (Sclove 1995:24)

Sclove draws on the earlier work of Langdon Winner who has articulated what he calls 'Political Ergonomics' (Winner, 1995:146). Winner demonstrates the close relationship between political life and technological systems and patterns and he points out that:

> At least as important now are the artificial patterns, including technology-centred patterns, that affect civic culture - the broad range of social relations, personal habits, popular beliefs, and styles of communication that give any political system its distinctive character. Of course, not all of what comprises civic culture is directly connected to the design and making of technological devices. There is more to it than that. But if the traditional concerns of 'politics as making' are to

> respond to the challenge at hand, technological design must become a focus of political reflection. If Alexis de Tocqueville were visiting the United States in the late twentieth century, his book on its customs might well be entitled 'Technology in America'.
>
> (Winner 1995:156)

5.4 …framing Design

Of course, I'm sure that our collective political consciousness is being enhanced. For example, we are aware that environmental issues must be addressed and, so far as the world of design is concerned, we have authors' frameworks of principles not only to apply but also to compare and contrast. From two decades apart I would offer as examples for critique Mayall's (1979) Ten Principles of Design and McDonough's (in Ellyard, 1999:111) nine 'Hannover Principles' for sustainable design - so called for their articulation with the Hannover 2000 expo 'Humanity, Nature and Technology'. (appended)

5.5 Engaging technologies… We with them? Them with us?

5.5.1 Participation

At the level of participation, within our schools, in the professions or in societal decision-making concerning technology, serious issues remain for one (though by no means the only) group. As far as the educational and democratic arguments go, Grant put the case clearly:

> The absence of girls from technological-type courses may well have profound social and political consequences for a society that is highly dependent on technology. Individuals lacking the necessary skills and knowledge to understand and cope with the technology that impinges on every aspect of their daily lives will increasingly have to rely on technical experts - be it for simple technical repairs or for more important decisions regarding the very nature of our society. At present most women have little influence on technological decision-making at any level. This non-participation of half the nation's population in directing technological change must surely strike at the very foundations of democracy. To disenfranchise women from the politics of technology by denying them an adequate technological education is to deny them a most basic freedom and can only lead to alienation from and ignorance, or worse still, fear, of technology.
>
> (Grant, 1983, p. 217)

5.5.2 Technology and work - then and now…

There isn't only the sense of being positioned by the technologies we buy, use or live with. There is also considerable discourse on our relationship with the technologies with which we work. A hundred years ago, Morris articulated concerns about the depersonalising nature of machine-based production and the disengagement of the worker from the product (Morton, 1979). Current commentators note the agendas that control our potential to function in employment. For example, Luke (1992), in his elaboration of ‘cultural’ and ‘functional’ literacy, identifies the former for an elite and the latter for the masses.

Whereas the ‘traditional’ in the form of a ‘craft’ is seen as technology passé, computers are very much technology de rigueur. The critiques of Fry (1992) and Apple (1992) illustrate, ironically, the emancipatory role of the traditional and the technical role of the modern respectively. It is possible to share the concerns of Fry when he suggests that it is our very separation from technology, at least in its craft sense, which contributes to a de-humanisation.

> Besides whatever particular craft practices deliver, craft centres on the act of human making which is increasingly important to retain in the face of technologies that de-democratise the power to shape the world through one's labour. In such a context, craft inverts the historical trajectory of technology to shift the directive power of the making of forms away from the hand and machine-skilled labour into management maintained systems. In other words, it re-centres the human maker that advanced technology de-centres and displaces.
>
> (Fry, 1992:263)

5.5.3 Being us…

So entwined are we with our technologies that we seem not to see their effects. Yet we seem willingly affected, if not also effected, by them. Earlier this year I framed an informal workshop for my local branch of the World Education Fellowship around the title 'Who were we? Who are we? Who will we be?' The questions offered a vehicle to talk about our very existence and development as a species. Our capacity to design and make sets us apart from other species although our capacity to head into the future uncritically may, in another sense, not set us so far apart at all! Several authors illustrate well the very essence of our 'being with’ technology and the construct of technology as cultural practice (see eg Whiteley, 1993; Pursell, 1994; Buchanan & Margolin, 1995).

5.6 The existential…

The kinds of scenarios I have discussed - of relationships, societal organisation, culture and work - all bring one to ask 'Can we be who we are without Technology?' (As I have suggested, I view thought and language similarly. It seems to me that these three are of our essence). There are enough technologies in the first five minutes of anyone's day to construct a semester's study of species and technology. Short of a complete return to our natural state - whatever that might be, and I doubt if our minds would allow it - it may well be that we really are who we are because of the technologies we inhabit or because of the technologies that position us in our world. Thus we come to the existential philosophy of our business.

Some colleagues will be aware of Florman's (1994) text The Existential Pleasures of Engineering where he writes:

> Yet, what if existential searching were to reveal at the core of the human spirit a love for engineering? Or what if engineers, seeking the basis of the satisfactions they derive from their work, were to come upon the very soul-satisfying elixir that existentialists prize?
> My proposition is that the nature of engineering has been misconceived. Analysis, rationality, materialism, and practical creativity do not preclude emotional fulfilment; they are pathways to such fulfilment. They do not 'reduce' experience, as is so often claimed; they expand it. Engineering is superficial only to those who view it superficially. At the heart of engineering lies existential joy.
> (Florman 1994:101)

Compare and contrast this with Hacker's (1990) analysis of 'The Erotic in Technology'. She, too, looks at engineering and, later, deconstructs Florman's work. She says;

> Let us consider the field of engineering, foregrounding the passionate context of this occupation. This field, the apparent epitome of cool rationality, is shot through with desire and excitement. Much of this excitement stirs the mind. It is as though an intricately shaped erotic expression finds its most creative outlet today in the design of technology. The contemporary images of eroticism and of machines and systems reflect the imagination of the designer. How could it be otherwise if any human venture?
> As with any human and social activity, some care a lot and some don't give a damn. Technical skills and activities and erotic skills and activities leave some cold, but fire the imagination of many. The latter, rightly or wrongly, view the disinterested as alienated, pathological, or deficient in some way. The disinterested may view the aficionado as obsessed, either with sexuality or with technology.
> (Hacker 1990:206)

5.7 …and the phenomenological

I conclude this section with a visit to the work of Don Ihde and his argument that technologies '… must be understood phenomenologically', not as objects but in terms of our experiences, indeed, as a 'human-technology relation'. I can express his third (of three) theses on 'Technology as Cultural Instrument' no better than he:

> Thesis Three. The dimensions of technology transfers are never simply economic or productive, but multidimensioned and involve basic cultural and existential interchange. This is therefore a rejection of any foundationalist or reductionist explanation and an opting for a more multidimensional and phenomenological

> model of understanding. It will involve utilization of a variation theory such as originated with Husserl, but now adumbrated into the historical-cultural domain both through interdisciplinary use of historical and anthropological insights and of imaginative variants upon these.
>
> (Ihde, 1993:34)

Existentialism and phenomenology have much to offer us in our understandings of the relationship between ourselves and our technologies. Today we can converse, rather than just speculate, about robots and about - at least at a restricted level - artificial intelligence. At the beginning of this decade Kurzweil (1990) titled his text 'The Age of Intelligent Machines'. Two years later Caudill (1992) sub-titled her text 'Building an Artificial Person' (note 'person') and used the title 'In our own image'. This year, Kurzweil's (1999) text is subtitled 'When computers exceed human intelligence' and the title? 'The Age of Spiritual Machines'. In the same timeframe there has been growth in the field of nanotechnologies – machines built on atomic scales and, it is proposed, capable of travelling through the bloodstream. The landmark author, Drexler (1996) titled his text 'Engines of Creation'.

None of these authors is of the science-fiction genre; indeed, their works are highly appropriate as studies of Design, and of Technology. They offer excellent material for exploring what I see as a key concern for education as well as for professional Design and Technology practice, namely, intention. Are we willing and able to encourage critique at the very time of intention? What are the intentions of those who would design – let alone manufacture – new or 'improved' products, systems or technologies? In the desire to humanise technologies, we may be failing to explore the dehumanising (or the continued technologisation) of our 'selves'.

5.8 A summary of our look at Design and at Technology

What, then, is to be said about the scenarios I have just presented? I pose three questions:

- Where are we, as conscious beings, in relation to the technologies we design and use?
- Are we conscious of the extent of our depersonalisation or dehumanisation by technologies in our lives, relationships or work?
- What are our intentions in designing technologies and systems that we claim to be thinking, conscious or even human?

To know who we are, in our essence and through our consciousness, is to really know our technologies. To know both will allow us to create ethical and democratic futures. As Buchanan says in his chapter 'Rhetoric, Humanism and Design':

> In our contemporary world, design is the domain of vividly competing ideas about what it means to be human. However, the exploration of design does not break our connection with the past. The central themes and commonplaces of design – power and control, materialism and pleasure, spirituality, and character – reveal deep continuities with ancient philosophic tradition. Indeed, the pluralism of

> design in the twentieth century is intelligible because it rests on a pluralism of philosophic assumptions which are familiar. The exploration of design is, therefore, a contribution to the philosophy of culture in our time.
>
> (Buchanan 1995:55-6)

6 Design and Technology and Citizenship Curriculum Issues

I will now try to bring together what I've said so far in ways which might inform curriculum design but which certainly demonstrate Design and Technology's role in Citizenship Education.

I see democracy as an ethically focussed ideal - to be striven for, worked for - not something which one learns from the book or simply discovers. So I suggest that, by definition, if it were ever achieved then it would cease to be an ideal. It is a form of social and political organisation which is dynamic and can constantly re-create itself.

There seems to be a case that the current state of affairs for democracy is poor, that some democracies are fossilising, ceasing to be vibrant. In climates where critique and criticism are unwelcome then they atrophy, and cynicism - an insidious reciprocal of idealism - sets in.

A healthy democracy needs a literate citizenry (Freire, 1972) – indeed a critically literate, not just a functionally literate citizenry. There is a proliferation of theorising to suggest that there is no such thing as a single, universal literacy. The debates and issues from the field of technological literacy are informative. We can construct technological literacy on the most basic of instrumental or operational lines - perhaps of skills and techniques. Thus we 'teach the technology' and students learn it – it is essentially technical. We can also look to 'learning through' technology. Here, in the hermeneutic-interpretive sense students can make meanings and understandings of their world – perhaps through designing products of their own. It is essentially practical. However, at an emancipatory level, students reflect on, critique, deconstruct and evaluate technologies in their fullest formulations. This is critical technological literacy. All of these senses of technological literacy are important and I would argue that a truly technologically literate person is empowered through all three senses to participate in and shape democratic life.

In an education for participatory democracy, and in preparing students for citizenship in our technologically-practised culture, it is simply not enough to constrain their learning to competence or basic applications. The issues that our societies create for themselves are of a political-technological blend and this has been the case for millennia. Hacker concludes her piece by envisioning that:

> …the organization of material and energy to accomplish work, embedded in relationships of democratic technics, might once again unite technology and eroticism, freed of the authoritarian dimension that has distorted both since military institutions emerged some 5,000 years ago.
>
> (Hacker, 1990:222-3)

Sophisticated applications of both political and technological literacies are called for and these can only be articulated in climates of reasoned criticism - whether in the classroom, in forums such as this, or in a society wishing to be truly democratic. If our students are to be ethical citizens then we will need ethical educators delivering an ethical curriculum for an ethical society. 'Right practice' in Design and Technology is 'right practice' for a democratic society. As Gill & Reid (1999) argue, democracy should be both the purpose of schooling and the model on which its curriculum is structured.

As we think of our students and their citizenship I suggest that we have plenty to offer through Design and Technology curriculum. Today's is the world of the blundering oxymoron – 'military intelligence', 'economic rationalism', and the 'discriminating consumer'. Today's is the world where the term 'Luddite' is used offensively towards anyone who dares to speak out against a particular technology. Today's is the world of instrumental and reductionist reasoning. Today's is the world of valuing material capital and viewing the individual as commodity. Today's is the world of government- and multinational-controlled suppression of knowledge and criticism (Tudge, 1999:46). Today's is the world of the telephone as a tool of mutual surveillance. Today's is the world of near total global communications surveillance (all phones systems including mobiles must now embody circuitry for monitoring purposes - Riviere, 1999). Today's is the world of plant and human gene patenting (Berlan & Lewontin, 1999).

This is the world that the Citizenship Education writers would have students learn 'social and moral responsibility', 'community involvement' and, I suspect, a very narrow 'political literacy'. This is also the world in which students are to 'discover democracy'.

In a phrase in the vernacular, we might construe a good quality Design and Technology education as 'bullshit spotting'. I might put it more eloquently and assure those Citizenship, and other, curriculum designers that good quality Design and Technology Education recognises: the polypotency of technologies; is concerned with dynamism and change; is constantly weighing-up competing variables; articulates ethics, values and the aesthetic; and, is futures-focussed.

I put it to Design and Technology educators that instrumental reasoning, instrumental technology, instrumental assessment systems (see Kimbell, 1997) all lead to instrumental democracy. It is more important than ever to keep alive the lights of holism, criticism and contestation as the democratic indicators of our field - one which must be comfortable with the continuous journey, never the destination.

7 Conclusion...or re-creation…?

I offer two snapshots of challenging paths we might explore. The first is from the broad discussion of the design-technology-politics relationship.

> Under present conditions it seems unlikely that a humane, democratically motivated, broadly effective political ergonomics will emerge. But it is also true

> that in modern society one of the most grievous manifestations of society's rudderless condition is a widespread atrophy in the ability to imagine what an alternative society and its technologies would look like. Even those eager reformers and revolutionaries who have succeeded in achieving real power in the twentieth century have shown a woeful ability to apply the powers of human creativity in shaping a more positive connection between human purposes and the structure of technical means. To realise a better connection between politics and the design of things is the challenge that awaits us.
>
> (Winner, 1995:168-9)

The second extract, already five years old, speculates on curriculum redirection.

> Rather than necessarily associating technology studies more or less exclusively with workplace reform and the economy, perhaps as much emphasis needs to be given to the critical reimagining of a 'post-industrial', postmodern culture and the effects of new technologies and media culture on the emergent generations, as the citizenry of the future. Hence cultural and identity dynamics and new forms of lifestyle within an increasingly digitalised ecology might well become more overt curriculum concerns, supplementing current emphases on 'knowledge' and 'expertise': a new 'life-skills' curriculum, in short, bringing together 'really useful knowledge', 'technological literacy', 'practical learning', and 'civic courage'. This remains a matter for further enquiry and investigation.
>
> (Bigum and Green, 1994:121)

Perhaps we, the profession, lack the critical confidence and/or the theoretical base to articulate the profound significance of Design and Technology to the general education of all students. To this end I welcome and accept the 'Invitation' presented to us by the conference organisers and I encourage you all to enter, critically of course, into this 'running conversation'.

We all have a fundamental role to play in citizenship education for vital and contested democracy. This is not something to be either marginalised by us or compartmentalised by instrumentally rational curriculum planners. Of course we could creep around, like Basil Fawlty, whispering “Don't mention the temperamental elephant” in case we awaken the critical, engage the ethical or even create a truly technologically literate society. As if democracy mattered…

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Appendix A MAYALL’S 'TEN PRINCIPLES'

THE PRINCIPLE OF ITERATION
Design requires processes of evaluation that begin with the first intentions to explore the need for a product or system. These processes continue throughout all subsequent design and development stages to the user himself, whose reactions will often cause the iterative process to continue with a new product or system.

THE PRINCIPLE OF CHANGE
Design is a process of change, an activity undertaken not only to meet changing circumstances, but also to bring about changes to these circumstances by the nature of the products it creates.

THE PRINCIPLE OF RELATIONSHIPS
Design work cannot be undertaken effectively without establishing working relationships with all those activities concerned with the conception, manufacture and marketing of products and, importantly, with the prospective user, together with all the services he may call upon to assist his judgement and protect his interests.

THE PRINCIPLE OF COMPETENCE
Design competence is the ability to create a synthesis of features that achieves all desired characteristics in terms of their required life and relative value, using available or specified materials, tools and skills, and to transmit effective information about this synthesis to those who will turn it into products or systems.

THE PRINCIPLE OF SERVICE
Design must satisfy everybody, and not just those for whom its products are directly intended.

THE PRINCIPLE OF TOTALITY
All design requirements are always interrelated and must always be treated as such throughout a design task.

THE PRINCIPLE OF TIME
The features and characteristics of all products change as time passes.

THE PRINCIPLE OF VALUE
The characteristics of all products have different relative values depending upon the different circumstances and times in which they may be used.

THE PRINCIPLE OF RESOURCES
The design, manufacture and life of all products and systems depend upon the materials, tools and skills upon which we can call.

THE PRINCIPLE OF SYNTHESIS
All features of a product must combine to satisfy all the characteristics we expect it to possess with an acceptable relative importance for as long as we wish, bearing in mind the resources available to make and use it.

Mayall, W.H. (1979), *Principles in Design*, Design Council, London

Appendix B McDonough's 'HANNOVER PRINCIPLES'

1. Insist on the rights of humanity and nature to coexist in a healthy, supportive, diverse and sustainable condition.

2. Recognise interdependence. The elements of human design interact with and depend upon the natural world, with broad and diverse implications at every scale. Expand design considerations to recognise even distant effects.

3. Respect relationships between spirit and matter. Consider all aspects of human settlement, including community, dwelling, industry and trade in terms of existing and evolving connections between spiritual and material consciousness.

4. Accept responsibility for the consequences of design decisions upon human wellbeing, the viability of natural systems, and their right to coexist.

5. Create safe objects of long-term value. Do not burden future generations with requirements for maintenance or vigilant administration of potential danger due to the careless creation of products, processes or standards.

6. Eliminate the concept of waste. Evaluate and optimise the full life-cycle of products and processes to approach natural systems, in which there is no waste.

7. Rely on natural energy flows. Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate this energy efficiently and safely for responsible use.

8. Understand the limitations of design. No human creation lasts forever, and design does not solve all problems. Those who create and plan should practise humility in the fact of nature. Treat nature as a model and mentor, not an inconvenience to be evaded and controlled.

9. Seek constant improvement by the sharing of knowledge. Encourage direct and open communication between colleagues, patrons, manufacturers and users to link long-term sustainable considerations with ethical responsibility and re-establish the integral relationship between natural processes and human activity.

McDonough added the following explanation to the document.
The Hannover Principles should be seen as a living document committed to the transformation and growth in the understanding of our interdependence with nature, so that they may adapt as our knowledge of the world evolves. These principles have been adopted officially by the City of Hannover and are being used by design-based professionals, particularly in North America, Europe and Australasia. (Personal communication with author).

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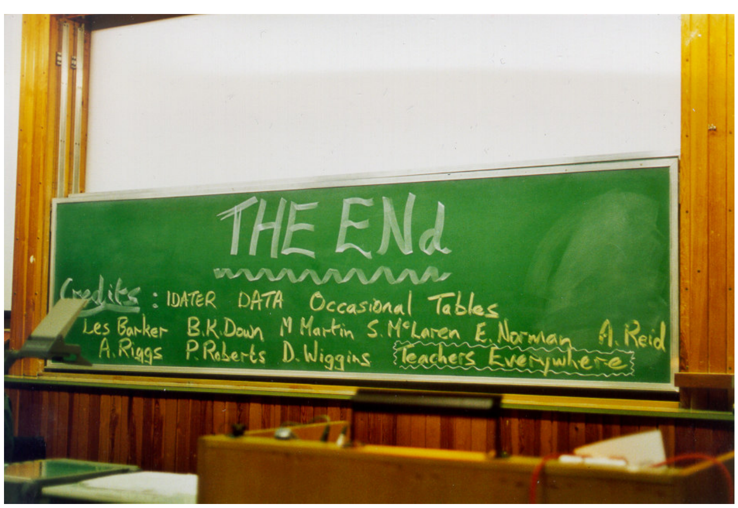

Design as a framework for innovative thinking and learning: how can design thinking reform education?

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The need for educational reform has led to much research documenting the value of experiential learning and creative problem solving to increase relevance and motivation in learning. Design, which may be succinctly defined as purposeful thought and action, can serve as a framework and catalyst for teaching and learning strategies that promote innovative, high end thinking, cooperative teamwork, and authentic, performance assessment.

This keynote will feature research findings and two models of large-scale applications of design education in the K-12 curriculum. Both projects are funded by major grants from the National Endowment for the Arts and by the Department of Education in the United States. As models of best practices and applied research that have been assessed and documented, they can provide useful and valuable examples for other art educators and educational sites. This research was conducted through the "Design for Thinking Teaching Institute, at The University of the Arts, Philadelphia, Pennsylvania, USA, which also was the host site for the National Design for Thinking Network and the Design Link for Teaching the Arts, Link-to-Learn projects. Other sites and research will also be addressed.

Keywords: Design, thinking, research, teaching, learning, model

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As the complexities of our technology-driven society intermix with the erosion of traditional lifestyles and values, it is only natural to look to education for answers on how to prepare children to cope with these new demands. After all, it is the young child who is the most vulnerable and affected by societal changes and, next to parental or family influence, formal education commands the largest block of a child's time and attention for more than a decade of his or her early life.

As educators grapple with their new role and inherited responsibilities, it has become increasingly challenging to find a pedagogical strategy that addresses not only content but context, in a world that is changing faster than our antiquated educational systems can handle. This scenario raises big questions which we must study from a new perspective. What are the basic skills and knowledge that should be the priorities of education? What does an educated person need to know to succeed in a career and daily life? What subjects are most important in the crowded school curriculum? What is the best strategy for teaching critical skills and knowledge? Are the "3 Rs" - reading, writing and arithmetic, still the foundation of our fundamental school system, or are other subjects, including technology, now part of that essential list of content disciplines? The questions are daunting, but even more complicated by the fact that many students have become disenchanted with the value of education, as evidenced by the continually growing drop-out rate of 30 - over 50% in the U.S., especially in our urban and rural high schools. The reason most consistently cited by students who drop out is that school is not relevant to their needs and lives, is often considered boring, and, in general, it is often perceived as a negative, meaningless experience.

International awareness of the need for effective educational reform has led to an increased interest in research on the brain and strategies for teaching and learning that are more motivating and relevant to students of all ages. How can students be taught to be more creative in their thinking and more capable of integrating knowledge and skills learned from diverse subject areas into practical and inventive solutions to daily problems? How can learning be more relevant and meaningful, touching the soul of education? What current research can be used to guide this process of educational reform and where will it lead us?

This keynote presentation will share several examples of pertinent and current research findings which point to design-related solutions, followed by a proposed “Design for Thinking” model, and illustrated by examples of programs that have proven to be effective pedagogical strategies, including two programs from The University of the Arts. Both of these projects were funded by major grants from the National Endowment for the Arts and by the Department of Education in the United States.

Design, as I am using the term, may be succinctly defined as “purposeful, problem solving thought and action,” or “creative thinking and problem solving action, which has no single answer, but may result in one of many effective solutions.” Design in education can apply to the discrete discipline, as taught in industrial, graphic, interior, architectural or clothing design, to name a few. In this case it is usually found within the art department as part of that curriculum. However, a second and perhaps even more provocative way of viewing design is in the context of a pedagogical model involving “design thinking.” This is a more generic application of the thinking that is inherent to the art-related, creative process of invention.

To examine educational research that is related to the most urgent needs in educational reform, we must first look at the science of learning studies on how the brain learns. This cutting-edge research will profoundly impact teaching and learning strategies in the future, replacing much of the trial and error wisdom, accumulated through years of practice in the traditional classroom. From these studies we will examine a new paradigm that may better accommodate students’ physical, emotional, and mental needs for the future. Although many educators are reluctant to abandon the familiar practices of traditional instruction, some are cautiously grappling with innovative but unproven elements of reform in hopes of finding a more effective approach to teaching and learning. These educational pioneers are eager to develop new ways of teaching and learning as a modern equivalent to the “Renaissance ideal. ” This ideal person is one who is able to meet the rapidly changing needs of the “Information Age” and the demands for a new kind of educated worker, who is flexible but rational, an “out-of-the-box” thinker and problem solver. This kind of inventive thinker is a throwback to the Renaissance where an artist also functioned as a designer and creative thinker like Leonardo da Vinci - whose work harmoniously spanned the disciplines of art, science, anthropology, maths, and technology.

It is interesting and perhaps insightful that models of creative genius, problem solving, and intellectual and moral balance are often symbolically represented in the work of artists, such as Leonardo da Vinci, Rodin's, "The Thinker," or in the unique architectural creations of Frank Lloyd Wright. For centuries the work of visual artists and designers has been referenced as visible evidence of innovative thinking and brilliance. Yet, ironically, this "design thinking" has never been translated into educational practice. The presence of teaching design in basic education is minimal at best. The value of design thinking in education is often overlooked for its potential as a dynamic and experiential strategy for teaching creative problem solving, reflective, analytical thinking, and the process of "learning to learn." These attributes are becoming increasingly important as the proliferation of information makes memorization impossible, and in some cases detrimental and inaccurate.

Another pertinent example of educational skills needed in the new workplace is evidenced in the published dialogue of James S. Houghton, Chairman, National Skills Standards Board, and Retired Chairman and CEO, Corning Incorporated. In his words

> … the importance of 'thinking skills' to the new workplace is evident in the high-performance teams that are today bridging the divide between manual and mental work in corporations throughout America (and globally), handling all facets of project coordination, group dynamics, and consensus building. (The Getty, 1997)

Houghton further refers to another study which revealed the estimate that six to seven million jobs were expected to be created in the U.S. in the last years of the century, but it was also estimated that less than half of those entering the workforce at that time would be equipped for these newly created high-skill jobs (The Getty, 1997). Unfortunately, this has proven to be true.

To accommodate the needs of learners today, and in the decades to come, a new "paradigm shift" is needed for education. In comparing the practices of the 1980s to the emerging paradigm of today, there are dramatically sweeping changes that are being acknowledged as examples of "best practices." The new paradigm shift includes the following:

• Instruction vs. Construction

Teachers have long relied on the practice of lecture and written content as the primary method of instruction. Students were taught by being told or perhaps shown, but students seldom learned by making and doing, and through their own exploration. Not only has research on learning styles and multiple intelligences promoted the need to expand the modes of instruction, but these findings have also supported the greater effectiveness achieved through the constructivist approach to learning, in which the student pursues an experiential discovery of knowledge by using information in a relevant, hands-on context. This reinforcement of making and doing in a way that is related to personal interests and needs makes the learning experience rich and memorable.

• Linear vs. Hypermedia

There are distinct differences in students' interests and habits of learning that can be largely attributed to the influence of television, multimedia, and the internet. The sensory overload and fast paced bombardment of visual images has affected the students' attention span and habits of learning so that students no longer think and operate only with linear logic and singular focus. Students must learn to selectively process and deal with visual overload and to quickly and effectively evaluate and respond to stimuli that are pertinent and appropriate to their needs and values.

• Teacher Centered vs. Learning Centered

The traditional paradigm places the teacher in the role of selecting and directing the discipline content and thematic applications, in time blocks he or she thought to be most appropriate. Students were passive learners with little influence in directing their own destiny for learning. In the new paradigm students determine the context and appropriate ratio for learning in the various disciplines, drawing upon information and skills as needed to complete the interdisciplinary task at hand. Such thematic learning is not only relevant and motivating, but highly effective in empowering the student to take responsibility for his or her own learning process and performance outcomes.

• Absorbing Material vs. "Learning to Learn"

For decades the measure of a student's intelligence was his or her proficiency in memorizing and reiterating facts and information on primarily cognitive verbal and mathematical tests. This process, described as 'teaching the basics,' relied on the assumption that there was an identified and accepted universal cannon of knowledge that was fundamental and comprehensive to each academic discipline. As information exponentially multiplies, it is no longer possible or practical to memorize all the factual knowledge considered basic to any one subject. Students are better served by "learning to learn," so that they can ably retrieve and use information in response to a need or an interest. This process emphasizes understanding of information in a relevant context and encourages learners to use metacognition as a process for reflecting on and understanding their own thinking and creative problem solving.

• Teacher as Transmitter vs. Teacher as Facilitator

In contrast to the teacher as the "sage on the stage" and primary source of knowledge, the focus is now on student with the teacher as the facilitator of learning. His or her role is to guide and support the student in self directed research and exploration. This approach individualizes instruction to accommodate students' preferred learning styles and thematic preferences.

• <u>Learning for School/Work vs. Learning for Life</u>

Closely related to individualized instructional approaches is the need to customize curriculum content to a "real life" context for the learners. Students value and remember information that is perceived to be useful and relevant to their lives. This knowledge then provides a foundation on which they can build over a life time, drawing upon the skills and knowledge that are needed in an integrated context. This approach is critical to equip students to become life-long learners, both in a formal academic setting and through professional development in the work place and home. Learning for life is also congruent with the need to continually learn new information, technology, and skills to adapt to the needs of industry and society.

• <u>Evaluation vs. Performance Assessment</u>

Measurement of accomplishment in learning information or skills has traditionally been conducted by the teacher with the focus on the effectiveness of the final outcome or product. Rubrics, or guidelines for measurement, were generally set by the teacher or other external sources, with the students having little knowledge or understanding of how their product or answers were graded. In the new paradigm the emphasis has shifted from product to process, with the analysis of how a student learns and progresses being perceived as more important than the end result. This concept also assumes that the student will be a part of the reflective assessment process and that he or she will be charged with the responsibility of articulating what they have learned, what worked and what did not, and why. In answering these key questions, students are required to employ higher order, critical thinking and problem solving, measuring and comparing the outcomes at each stage of development and then ultimately judging the final results in the context of real life applications. Another benefit of this approach is that it acknowledges that students can learn as much, and perhaps more, from what was not a successful result as they can from an outcome that meets the intended goal. Students can gain confidence and independence by learning to analyze their own learning and from having to articulate and defend their evaluation of the final outcome.

• <u>Verbal and Textual Communication vs. Visual Communication</u>

Although dependence on visual imagery to formulate our thinking has always existed, the priority of teaching students to communicate through text has long dominated our educational paradigm. This approach is changing, however, due to the influence of globalization and the competition of visual imagery in the marketplace. As world cultures interact more fluently through physical travel, television and the internet, the hindrance of not knowing each other's respective languages has prompted the necessity to design international visual icons to symbolically communicate information. The motivation of conducting business on a global scale has also been a catalyst for accelerating the need to communicate more effectively through the visual medium in both an overt and subliminal way. The sophistication of visual communication and graphics has benefited and been guided by findings in research and brain studies. Scientists, psychologists, artists and designers acknowledge and explore the pervasive nature of "visual thinking," which "pervades all human activity, from the abstract and theoretical to the down-to-earth and everyday" (McKim, 1980).

In summarizing the focus of the new paradigm for learning, continually changing global access to information through technology, along with the perpetual evolution of research findings, are factors that erode the constructs of basic knowledge, making process rather than product the logical emphasis for students' education. In short, students must "learn to learn." By understanding their modes of thinking and developing skills for analyzing a need or *intention,* they can learn how to *define* available resources and parameters, *explore* creative options, *plan* and organize a potential solution, adaptively *produce* an outcome, and *evaluate* the results compared to the set standards of the intention. Optimally the students must also be able to *integrate* and relate this information with other relevant applications. This is designing! It is also high end thinking which draws upon both hemispheres of the brain, composites of learning styles, and ways of knowing. This is also the attainment of knowledge to the most applicable and memorable degree, and is facilitated by the "Design for Thinking" model known as I/DEPPE/I (Burnette, 1996; Norman, 1996).

In identifying the desired outcomes of an effective education, the American public and educators are in agreement on one issue: what students most need to gain from education is the ability to demonstrate higher order thinking, not only on standardized test scores, but more importantly in the contest of life. This goal for achievement in life is measured more broadly in the quality of how people work, play, interact, and live in our global and increasingly visual, high-tech society. As committed educators who strive to engage students, provide practical, relevant skills, and help them creatively integrate knowledge in the context of future careers, perhaps we need to rethink the "Da Vinci model." Research studies support the strategies and processes used in art and "design thinking" as skill developers critically needed to hone the desirable characteristics of humanity - to think, reason, communicate and create innovative and appropriate solutions.

In this "decade of the brain," recent psychological and neuropsychological research provides a growing body of scientific evidence and related literature, which could inform and influence how art education is designed. Numerous studies support and identify the attributes of a strong art and design education for developing the skills of creative and analytical thinking, perceptual sensitivity, perseverance, communication, and inventive problem solving. Among the most provocative of the research studies is the work of Howard Gardner, related to his theory of "multiple intelligences." His definition of "intelligence" is "the ability to solve problems, or to create products, that are valued within one or more cultural settings" (Gardner, 1983). Having initially identified seven, now eight and a half, comprehensive categories for "intelligences," he adamantly describes each as being distinct and definitive. Included in these are spatial and bodily-kinesthetic intelligences, which are deviations from the commonly perceived idea of intelligence as a blend of logical-mathematical and linguistic abilities. These art and design-related ways of learning recognize the unique characteristics, which are inherent in art making and "design thinking" and the benefits and importance of cultivating the full range of cognitive, affective, and psychomotor skills.

"Design Thinking," is a term defined by consensus in the National Design for Thinking Institute (August, 1998), supported by the National Endowment of the Arts, attended by designers, architects, administrators, and educators in higher education, K-12 art and general education. The Institute also included directors of art and design related museums, representatives of departments of education, as well as editors of two national magazines and an educational publishing company. After analysis, discussion, and careful weighing of each word and its meaning within the context of the design process, the following definition was adopted: "Design Thinking" is an inventive process, through which problems are identified, solutions proposed and produced, and the results evaluated. This concept of design is also based on the underlying principles of art making with practical application. Succinctly stated, it is purposeful, problem solving thought and action (Burnette, 1996; Norman, 1996).

Another thought provoking interpretation of design is provided by David Perkins in his book, *Knowledge As Design* (1983). Perkins describes design as "a structure adapted to a purpose." He further explains that "knowledge as design poses a provocative metaphor. Indeed, perhaps knowledge is not just *like* design but *is* design in a quite straightforward and practical sense." Acknowledging that higher order thinking and integration of information into a relevant context are part of the design process, Perkins' metaphor offers a compelling argument for the value of incorporating design thinking into the fundamental educational curriculum.

Intelligence, not unlike design, is also an ambiguous term with multiple meanings and interpretations. Both words are used to describe aspects of human uniqueness and function that are fundamental and essential to our very survival. The confusion that clouds the two terms, intelligence and design, stems in part from the definers' personal perspectives and experiences, which, in turn, colour their meaning and context. The interpretations are further hindered by our limited human knowledge about the rather magical processes of complex creative thinking and related human feelings and actions. We are still mystified by our ability to reason, to invent, and to solve problems at all levels in our daily lives and are consequently uncertain as to how to facilitate that level of learning.

Ironically, it is the characteristics of creative design and intelligence that distinguish humans from other animals, and yet we have much to learn about how these processes are cultivated and impacted by teaching and learning. The knowledge base to inform our teaching practices is expanding, however, with educational researchers adapting findings of brain research to theories of educational philosophy and applied practice (e.g., Bogan, 1969; Gardner, 1982, 1983; Jensen,1998; and Sylwester, 1995). Concepts such as multiple intelligences, brain based or brain compatible education are direct manifestations of this hybrid of neuroscience psychology and educational research, with some studies focussing more specifically on discipline domains, such as art and design.

As educators across our nation contemplate options for more effective teaching and learning, the science of learning and the influence of brain research are of paramount importance in setting priorities, policies, and pedagogical practices. This is true for all levels and disciplines, including design. However, to put theory into practice with effective results, teachers must be flexible learners and risk-takers, who are facilitators of knowledge and who coach and promote high level thinking using all forms of creative intelligence.

"Design for Thinking" is one model for investigation and exploration of multiple creative solutions. The I/DEPPE/I acronym, which stands for intending, defining, exploring, planning, producing, evaluating, and integrating, is basic and practical as a tool for learning both with individuals and groups. With groups it can facilitate team-building and group consensus.

The "Design for Thinking" model, initiated at The University of the Arts in Philadelphia, PA, USA, is based on more than a decade of intense and sustained studies of design thinking and ways it can be effectively applied to the education process. A sequence of projects have led to major sponsorship by the Department of Education for two consecutive grant projects based on the "design for thinking," I/DEPPE/I model, as developed and implemented through technology. The first of the two projects was Design Link for Art and Science, which involved four testbed middle schools, an art museum, a science museum and University faculty in a collaborative effort to apply the "design for thinking" model to the teaching of art and science using electronic media, the internet and videoconferencing technologies. As an Infrastructure Investment grant, the one-year project required development, technology training, classroom application and assessment.

The Design Link for Teaching the Arts project, which overlapped the Design Link for Art and Science project in the planning phase, built on the foundation of the previous project. It continued partnership with the four schools and it added museums and an Instructional Unit from the Pennsylvania Department of Education, which serves many schools in the rural, mountainous northeast portion of Pennsylvania. Retaining the "mentor teaching teams" from the original four testbed schools, the project expanded to include five additional urban schools in the Philadelphia area and eight rural schools in the northeast, mountainous part of Pennsylvania. Participating teacher teams from a total of 17 schools were provided with regular bi-weekly professional development classes and additional on-line support to help them learn and apply the I/DEPPE/I, design for thinking model, facilitated by technology, and focussed on ways in which the arts could be integrated into the curriculum. In addition to the emphasis on professional development for K-12 teachers, the project also provided regular instructional sessions and teaching mentorship for college education faculty and the pre-service teachers in Art Education. Curriculum was developed and implemented for each of these groups and large and small-scale assessment was conducted to measure the impact and effectiveness of design thinking and technology in teaching and learning.

The assessment of both of these projects yielded similar results. Both teachers and students found technology and the “Design for Thinking” model to be motivating, a facilitator to interactive, cooperative learning, and that they were helpful in organizing thought and actions. The challenge of not fully understanding and knowing how to use either was daunting at first, but became more comfortable as they progressed. Ultimately they felt that both design and technology were critical to their teaching and learning in the new paradigm and endorsed their inclusion strongly with comments such as the samples below:

> Although challenging, this experience has taught me a lot regarding the benefits of project-based learning, team-teaching, and continuously assessing work based on teacher, peer, and self-evaluation (teacher assessment, Design Link for Teaching the Arts, 2000).

> This program has really focussed on ’process.’ I so appreciate the I/DEPPE/I model and it was a key teaching tool for me this year. Students have constantly referred to it and often point their peers back to the model when something doesn’t work out in a scene or presentation. At last, something that is complete, simple and applicable. (theatre teacher assessment, Design Link for Teaching the Arts, 2000)

> In the first grade, the I/DEPPE/I model was utilized by asking questions pertaining to each letter, since this was the first introduction. Th art project with the students went well with wonderful results. (first grade teacher assessment, Design Link for Teaching the Arts, 2000)

To quote an anonymous statement by a Philadelphia high school music teacher who learned and used the model in this past year:

> The (I/DEPPE/I) model was the best part of the program for me because I could take the critical thinking model right back to my class in everything we did. The students started to call it the ‘peanut butter and jelly’ (basic structure for how to learn) model! Our final project was to design a musical that addressed teenager issues. The students worked in five teams and developed their musicals based on the model. They wrote and rewrote, they rehearsed and performed and completed their pieces. They evaluated the process and expressed how they would incorporate it in future work. At last! A technique that makes sense of learning.

Design, when taught within the structure of the “Design for Thinking” approach, is a means of creative problem-solving, that relates thought and action in a very direct and dynamic way. It involves the exploration of needs and functions to be considered; the context in which the problem exists; the audience or participants to be served or affected; the scope of the results you wish to achieve; and the means of evaluation that will measure the solution's effectiveness, either through conscious or unconscious judgment. Design, a visual art form with a practical outcome, offers a means of conceptualizing and visualizing, from problem to solution, a process essential to learning in life.

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PUBLISHED PAPERS FROM PREVIOUS IDATER CONFERENCES

Browser categories

Previous conferences have provided IDATER with a very rich research base and efforts are continuing to make this available to researchers world-wide. Most of the abstracts can now be searched on the IDATER website and the individual papers can be ordered through the IDATER office. In the early years keywords and abstracts were not always included, so many need to be added. In the Conference Books a number of different 'category systems' were used over the years. In 1999 it was decided to standardise the browser categories for the website as follows:

- Keynote Addresses
- 0-11
- 11-18
- 18+
- IT
- Technologies (other than IT)
- Initial teacher training
- Continued professional development
- Curriculum – content and development
- Curricula around the world
- Links with industry
- Modelling
- Values
- Assessment
- Design research Society papers

Of course, these categories are somewhat 'arbitrary', but they provide quick access on 'commonly asked for' topics. Not all the papers will appear on the browser, so a search facility has been provided. This searches both the 'keywords' and 'abstract' for each paper. These were not written for the papers published between 1988 and 1990, but the papers for these years have been included in the full list of published papers shown below.

IDATER papers from 1988-2000

Notes

(1) From 1988 – 1991 the Conference was known as the Design and Technology Educational Research and Curriculum Development (DATER) Conference, becoming 'International', and hence IDATER from 1992.

(2) The 1988 papers were published by Longman and are not currently available for sale individually via the IDATER office.

Author	***Paper Title***	***Year***	***Pages***	***Keywords***
Ager R	The development of an assessment framework for design & technology at key stage three	1990	30-34	
Ager R	Innovation in the assessment of technology within primary initial teacher education	1992	144-149	
Akinson E S	Approaches to designing at key stage 4	1995	36-47	
Albannai O	Technology education curriculum issues in secondary schools: a comparative study between Britain and Kuwait	1996	174-180	
Ali A & Price G	Effects on ethnicity on learning preferences in technology	1996	80-86	
Allison Y	What values do primary children attribute to everyday objects within their experience?	1997	4-9	
Allum J	Technology in context: a national support service for schools	1990	35-38	
Allum J & Reid H	Maintaining the quality and relevance of industrial resource materials for technology education	1992	48-53	
Andrade-Londono E & Lotero-Botero A	Curriculum development for technology education: a perspective from Columbia	1998	195-204	
Ankiewicz P	Aspects of the planning of technology education for South African Schools	1993	123-128	
Anning A	Technological capability in primary classrooms	1993	36-42	
Anning A & Hill A M	Designing in elementary/primary classrooms	1998	5-10	
Anning A, Jenkins E & Whitelaw S	Bodies of knowledge and design-based activities	1996	5-10	
Archer A *et al*	Case studies of food activities within design and technology	1991	9-13	
Atkinson E S	Identification of some causes of demotivation amongst key stage 4 in pupils studying technology with special reference to design and technology	1993	17-25	
Atkinson E S	Key factors which affect pupils performance in technology project work	1994	30-37	
Barker J	Craft, Design and Information Technology	1988	96-99	
Barlex D	A comparison between the nature of modelling in science and design and technology	1991	14-21	
Barlex D & Givens N P	The Nuffield approach to the teaching of mechanisms at Key Stage 3	1995	48-51	

Barlex D & Mitra J	The development of a design and technology webside for primary teachers	1999	6-11	D&T, primary schools, website, continuing professional development, resources
Barlex D & Wright R	Using the interent as an information gathering design and technology tool for the curriculum	1998	160-168	
Barlex D & Wright R	The role of resources in an immersive cross curricular D&T activity	1999	12-19	cross-curricular, industry/education links, D&T, resources, key skills, teamwork
Barlex D *et al*	Developing an approach to assessment for the elemenary science and technology curriculum of Ontario	2000	34-39	assessment, learning, primary, secondary, teacher development
Barlowe C	A case study introducing an innovative teaching and learning environment for a tertiary level graphic design unit	1999	20-28	tertiary, teaching and learning, case studies, project based learning, design processes, design cognition, design pedagogy
Barlowe C & Price A	Design education through case study methodology	1997	114-119	
Batchelor M	Strategies for planning and monitoring design and technology: the 'toolkit'	1989	24-29	
Baxendale P & Hook T	Bringing quality to industrial placements through the GRASP process	1992	162-167	
Beach R & Birtles L	Supporting creative 3D computing in the art and design community	1999	206-212	CD-ROM, computer supported design, creativity, 3D modelling, student learning
Beardon C	The design of software to support creative practice	1999	29-34	creativity, language, software design, theatre, users
Bell S	Using on-line whiteboards and internet with student D & T teachers	1998	169-174	
Benson C	Technology in the primary classroom - a way forward	1990	39-42	
Benson C, Johnsey R & Wiggins D	Inservice training for primary design and technology - is it working?	1996	121-128	
Billett E H & Owen W G	A response to the problems of teaching a highly technical subject to students without A level maths or science	1992	154-156	

Billett E H & Perkins M	The importance of judgemental factors in environmentally sensitive design	1994	136-142	
Billett E H & Turnock P	Practical building of industry/education links	1993	87-90	
Bird E	Higher educaiton into the new millennium - the challenge of teaching practical craft and design skills	1998	84-90	
Bird E	Brave new world - meeting the needs of society in the twenty first century, the role of design and design education	1999	35-38	product design, social technological, context
Black H, Devine M & Turner E	Developing diagnostic assessment instruments for technology	1990	130-132	
Blandow D	Integrative education and technological literacy	1991	23-32	
Boess S & Lebbon C	Integrating participant research with product design education	1998	118-124	
Bonner J	Developing advanced interface design guidelines from survey based and empirical research	1997	120-125	
Booth R J	The development of technology education in the United States	1988	83-90	
Bowen R	Using ICT to facilitate planning for primary school design and technology: a case study that also considers the impact of literacy and numeracy developments on the primary curriculum	1999	39-53	primary, curriculum, ICT, literacy, numeracy, education
Bowen R & Wade W	Economic and industrial understanding and primary design and technology	1990	43-47	
Bowen R & Wade W	Joining with industry: innovative curriculum materials for technology and science for primary schools	1993	76-81	
Bower R *et al*	Holiday at Howard Primary	1990	48-52	
Braga A E Jr	The improvement of equipment for cassava milling at the Mamiraua Sustainable Development Reserve (Amazonia - Brazil)	1998	205-209	
Brockley T	Distance learning in Gwynedd	1988	100-104	
Brown C	Girls, boys and technology: competence confidence and creativity in the primary years	1995	3-9	
Budgett-Meakin C	A global approach to design and technology	1990	53-55	
Budgett-Meakin C	Values to make the future work: the role of the appropriate technology approach in design and technology education	1992	20-24	

Burnette C	Using electronic design process portfolios in networked learning	1999	54-58	designing and learning, project-based learning, design technology, teaching and learning, cross-curricular, collaboration
Cabral Filho J S & Santos A P B	The critical usage of information technology at the School of Architecture of the Federal University of Minas Gerais in Brazil	1999	59-67	architecture, CAD, design methods, IT, meta-learning, student learning
Canavan B & Doughty G	Technological studies, physics and university entrance to engineering courses	1998	91-98	
Cawood J & Yates C A	The art of technology: a case study approach to linking art, design and technology at Key Stage 4	1992	75-78	
Chadwick E	Continuity between primary and secondary phases in science, technology and maths - an action research project in Hampshire	1989	30-33	
Chadwick E	Issues of progression in primary design and technololgy	1991	33-39	
Chadwick E	Linking science and technology in the primary school	1993	54-56	
Chambers J	Transferring capability	1989	34-42	
Chambers J & Egan B	Playing the King Alfred's game	1990	56-59	
Chambers J E	Designing and making – who needs it?	1988	10-14	
Chang D & Szalapaj P	A study of digital presentation techniques in arcitecture	2000	40-46	presentation, representation, visualisation, virtual environments, animation
Chen W-Y	Facilitating teaching and learning resources through the World Wide Web - case accounts of industrial design and living technology education in Taiwan	2000	47-54	industrial design, world wide web, learning resources, case account, living technology
Chen Y-C	Printed circuit board design in a school computer	1999	68-71	PCB, design, layout, via "educational" microcomputers
Chinyamunzore N	Role of technical/vocational education in informal sector development: a research report of a case study of Siyaso Industries in Haare	1997	90-98	
Chinyamunzore N N	Devolution and evolution of technical/vocational curriculum in Zimbabwe	1995	128-134	

Constable H	A study of aspects of design and technology capability at key stage 1 and 2	1994	9-14	
Conway R	Lessons for technology education from social, ethical and environmental audits	1999	72-78	audits, contexts, criteria, critical reflection, environment, ethics, quality, values
Conway R and Riggs A	Values and design and technology: exploring an issue	1992	28-30	
Cooke S, Jones A C & Mahoney R	Using multi-discipline assignments to enhance the development of transferable skills in initial teacher training	1995	100-110	
Coombs H	Contributions home economics can make to economic and industrial understanding through design and technology	1991	40-45	
Cooper A	Is it useful technology education?	1990	60-62	
Cooper A, Kicks M & Ghee W	The potential for using PIC chips in school control projects	1996	67-74	
Cubitt J L *et al*	The development of a 'flexible learning' strategy for design and technology	1993	171-178	
Davidson M, Evens H & McCormick R	Bridging the gap: the use of concepts from science and mathematics in design and technology at KS3	1998	48-53	
Davies D & Rogers M	Different views, different outcomes: how the views of science and design and technology gained develop and support effective classroom practice	1997	70-76	
Davies T	Modelling and creativity in design and technology	1996	16-21	
Davies T C	Managing the delivery of design & technology in secondary schools	1990	63-67	
Davies T *et al*	The six counties technology project - evaluative outcomes on management, teaching and learning	1991	46-52	
Davies T, Dillon P J & Gilbert J	Real contexts for design and technology. The "six counties technology" flexible learning project	1992	105-109	
Deere M T	Technology in the developing curriculum	1988	39-45	
Denton H	The role of group/team work in design and technology	1990	68-73	
Denton H G	Group task management: a key element in technology across the curriculum	1988	46-51	

Denton H G	The simulation of commercial design as an integrative strategy in National Curriculum Technology: some observations from the literature and field work	1991	53-60	
Denton H G	The group synergetic effect: some observations in relation to design with relevance to schools	1992	96-100	
Denton H G	The design and make task (DMT): some reflections on designing in schools	1993	70-74	
Denton H G	Critical point inputs with on-going design and technology project work	1994	60-63	
Denton H G	Developing design team working capability: some planning factors emerging from a survey of engineering design courses	1996	112-117	
Denton H G	The prior teamwork experience of first year undergraduate designers whilst at school: a focussing survey	1997	28-36	
Dickinson D J	The targeting of procedural capability through simulation and imaginary contexts	1991	61-72	
Dillon P & Davies T	Real contexts for design and technology: an evaluation of the six counties flexible learning project	1993	65-69	
Dillon P & Hayes N	Researching the interface between technological practice and technological education	1994	48-54	
Dillon P & Weller M	Industrial practice and the curriculum: the engineering construction industry schools liaison project	1993	82-86	
Dingalo R D	The selection of fabrication materials for design and technology in Botswana	1995	135-141	
D'Sena P D & Suharta H	An example of two-way developmental education in design technology: some preliminary findings of the benefits to eco-tourists from the west and villagers from central and eastern Indonesia of building simply solar ovens	2000	55-61	Indonesia, solar energy, internationality, project-based learning, culture, enironment
Durling D, Cross N & Johnson J	Personality and learning preferences of students in design and design-related disciplines	1996	88-94	
Egan B	Children talking about designing: how do young children perceive the functions/uses of drawing as part of the design process?	1999	79-83	designing, drawing, Key Stage 1

Egan B A	Design and Technology in Berkshire primary schools - survey 1986-7	1988	132-137	
Egan B A	How do children perceive the activity of drawing? Some initial observations of children in an infant school	1995	10-14	
Egan B A	Purposes in drawing: the significance of children's personal styles for design and technology	1996	48-52	
Eggleston J	Research and curriculum development in Design and Technology	1988	129-131	
Elmer R	Probing understanding: mapping learning	1994	160-164	
Elmer R	Mapping intentions	1995	74-79	
Elmer R	Probing understanding - an ethnographic study of student designing	1993	26-30	
Elmer R & Goodhew C	The role of materials in implementing design and technology education in South Africa	1996	196-200	
Elmer R & Perry D	Student independence and teaching design	1992	157-161	
Erkip F, Demirkan H & Pultar M	Knowledge acquisition for design education	1997	126-132	
Erol R, Press M, Thomas M & Cooper R	Design against crime': awareness in design education	2000	62-67	design knowledge, contexts, crime reduction
Evans M	Model or prototype - which, when and why?	1992	42-46	
Evans M & Wormald P	The future role of virtual and physical modelling in industrial design	1993	97-102	
Evans M, Cheshire D & Dean C	An investigation into the use of haptic modelling during industrial design activity	2000	188-193	haptic modelling, industrial design, education
Farrell A	A case study of technology education in a developing country: Columbia	1994	120-124	
Fathers J & Gill S	The virtual environment in design projects	1999	84-87	CAD/CAM, computer-supported design, design methods, information ergonomics, design educaiton
Finch I	Pupils consciousness of their mental processes	1991	73-78	
Flinn E A	Project success - an inner-city partnership	1990	74-79	
Flood J M	Technology education as a human right	1988	28-30	

Flood J M	Is 'Mickey Mouse' technology the way to beat the Japenese?	1991	79-83	
Flood J M	Failure modes and effect analysis: its possible application to national curriculum technology	1992	92-95	
Fowler C & Nicholson B	Graded assessment in Craft, Design and Technology	1988	113-121	
Garner S	A comparison of methods for researching into drawing within the field of design	1993	4-7	
Garner S W	Drawing and designing: exploration and manipulation through two-dimensional modelling	1989	43-50	
Garner S & Duckworth A	Identifying key competences of industrial design and technology graduates in small and medium-sized enterprises	1999	88-96	industrial design, graduate employment, competences, curriculum development
Garner S W & Norman E W L	Teaching design and technology in the National Curriculum: the use of video tape	1990	80-85	
Garner S W *et al*	The use of design activity for research into computer supported co-operative working (CSCW)	1991	84-96	
Garnham P	Science and technology: the interface 14-19	1989	51-55	
Gaul E	Home boom in Hungary: report of a nationwide design competition for 9-18 year old children	1995	142-147	
Gawith J A	Technology practice: a structure for developing technological capability and knowledge in schools	2000	68-76	cognitive models, knowledge, technology practice, techniques, teaching and learning, total technology
Georgieva V	Development of students' thinking through the school subject "Work and Technics"	1995	148-152	
Gill S	An industrial designer's approach to a virtual learning environment	2000	77-84	computer-supported design, designing & learning, ergonomics & design, industrial design, multi-media, product semantics
Gillham B *et al*	Realising a vision - a partnership approach to education, capturing the enterprising spirit of the young people of North Tyneside	1991	97-105	

Givens N	Early encounters with the Nuffield approach to design and technology	1997	37-44	
Gleave B *et al*	Trading with textiles': how to plan, make and market your designs at home and abroad	1991	106-111	
Gordon M L	Designing: the value-laden activity	1988	21-27	
Gradinscak Zlatko & Lewis William	An evaluation of curriculum changes in engineering graphics	1995	80-87	
Growney C	Gender inequality in technology…moving forward	1995	52-57	
Growney C	Gender inequality in design and technology…the pupils' perspective	1996	75-79	
Hansen R	The learning preferences and tendencies of technological education teachers	2000	85-89	technological education, teacher socialisation, experiential learning
Harrison G B	Frameworks for curriculum development in design and technology	1990	87-95	
Harrison M	Mechanisms of curriculum change at key stage 3 (paper 2)	1992	15-18	
Harrison M	Modelling in key stages 1 and 2 (paper 1)	1992	32-36	
Harrison M	Science in technology: technology in science	1990	96-99	
Harrison M E	Teaching methods in Technology	1988	69-74	
Harvey R O	Science and technology INSET in Devon Primary Schools	1989	56-60	
Heath J	Using food as a cross curricular activity and especially in relation to design and technology	1991	112-115	
Heath J	Easing the transition from KS2 to KS3 through work in the food area of technology	1992	79-81	
Hendley D & Jephcote M	A critical analysis of the operational aims and objectives for technology for 14 to 16 year olds in England and Wales	1992	4-8	
Hill B	Bionic - element for fixing the aim and finding the solution in the technical problem solving process	1995	154-159	
Hill B	Exploring the process of inventive learning in technology education	1996	33-39	
Hine A & Pine J	Credit where credit's due': encouraging and rewarding self directed learning through technology homework	2000	90-95	differentiation, disaffection, homework, learning, rewarding, self-directed
Hine A R	Capturing and comparing students conceptions of technology	1997	45-52	

Hodgson A R	Developing computer software applications for use in design and technology education	1992	131-135	
Hodgson A R	Developing links beween computer aided learning and design and technology teaching	1994	80-83	
Hodgson A R & Norman E W L	An examination of the potential of interactive video for supporting teaching and learning in design and technology	1993	113-116	
Hope G	Why draw anyway? The role of drawing in the child's design tool box	2000	96-101	drawing, sketching and design, cognition, design tools, modelling, designing and learning
Hopken G	A new curriculum for technology education in Schleswig-Holstein	1994	125-134	
Hopkinson M & Asquith G	School based teacher training - a partnership in balance	1992	150-153	
Hopper M & Downie M	Developing design and technology capability - rhetoric or reality	1998	54-59	
Hopper M, Hepton B & Downie M	Supporting the development of creativity and innovation - further issues examined as part of an extended curriculum development initiative	1999	97-106	innovation, creativity, curriculum development, teacher intervention
Horne S C	Shared visions? Architects and teachers perceptions on the design of classrooms environment	1998	210-215	
Horne S C	Establishing trend relationships in teachers' use of the classroom environment	1999	107-114	classroom environment, teacher training, teachers' mobility, classroom design, classroom use
Householder D & Bolin B	Technology: a cross-curricular catalyst	1992	88-91	
Howard G	Design and technology on-line	1996	40-46	
Humpherson J & Law J	"Working the line" Applying a multidisciplinary approach with design education	1993	184-190	
Hutchinson P	Whole language and design and technology education	1992	82-87	
Jackson B R	Engineering design projects for schools	1992	54-59	
Jackson G A	Technology and home economics	1991	116-122	
Jarvinen E-M & Twyford J	A rattling good experience': the development of children's thinking in design and technology lessons in English and Finnish primary schools	1998	11-16	

Jeffery J R	Developing capability through application based studies	1989	61-69	
Jeffrey J R	Design methods in Craft, design and Technology - are we being too prescriptive?	1988	15-20	
Jenkins D	Discovering what designers do	1997	154-160	
Jephcote M & Hendley D	Developing economic understanding through design and technology	1991	123-133	
Jervis A & Steeg T	Internet provision and use in secondary schools: the implications for design and technology	1998	175-183	
Jervis A & Steeg T	Growth in Internet connection and use in British secondary schools 1997-9: current practice in and implications for teaching and learning in design and technology	2000	102-112	ICT, Internet, secondary, D&T, policy, WWW
Johnsey R	Observing the way primary children design and make in the classroom: an analysis of the behaviours exhibited	1993	32-35	
Johnsey R	The place of process skill making in design and technology	1995	15-20	
Johnsey R	An examination of a mode of curriculum delivery in which science is integrated with design and technology in the primary school	1999	115-121	primary, case studies, cross-curricular, science
Johnsey R & Baynes K	Research priorities in pre-school and primary design and technology: a report of the IDATER Special Interest Group	1997	10-19	
Jones E, Harrison D & McLaren J	The product ideas tree: a tool for mapping creativity in ecodesign	1999	213-223	ecodesign, creativity, case studies, design processes, design tools
Jones P	Technology, creativity, and experience: Hermes dilemma and ethnographic authenticity	1999	122-129	ethnography, technology, subjectivity, experians, emotionality, attributions
Jones P S	Cultural constructs of technology: a different paradism for technology literacy	1997	53-60	
Keirl S	An episode in technology curriculum refinement: it's only another design brief…	2000	113-117	technology, curriculum design, technological literacy, process-content issues, stakeholder interests

Keirl S	The practise of ethics and the ethics of practice	1998	216-223	
Keirl S & King R	Innovations in professional partnerships in pre-school - year 12 technology curriculum: a state model within a national and an international context	1998	17-21	
Kent D & Towse P	Intransigence, ignorance or innovation: linking education with business in initial teacher training	1997	77-82	
Kimbell R	The Assessment of Performance Unit project on Design and Technology	1988	107-112	
Kolaveric B	Designing with regulating lines and geometric relations	1997	133-139	
Korkut F & Hasdogan G	The profession of industrial design in Turkey: the correspondence between education and practice	1998	125-131	
Kumar K L	Internet design node for Africa	2000	118-121	Internet node, Africa, Botswana, student, design
Kwaira P	Prospects for design and technology with Zimbabwean teachers through distance education - a pilot study	1996	186-190	
Kwaira P	Problems experienced by teachers in their efforts to implement the 'design and technology' approach in the teaching of technical subjects in Zimbabwe	1998	224-229	
Lawler T	Exposing and improving the metacognition of designing through practical structured workshops	1997	205-211	
Lawler T	Exposing the gender effects of design and technology project work by comparing strategies for presenting and managing pupils' work	1999	130-137	design methods, design pedagogy, designing, gender studies
Lewin R H	Craft, Design and Technology and the gifted child	1988	5-9	
Lewis A	Accommodating technology in schools	1990	102-106	
Lewis T	The skills and qualities of students entering design and technology initial teaching education	1996	147-152	
Liddament T	Using models in design and technology education: some conceptual and pedagogic issues	1993	92-96	
Liddament T	Technological literacy: from functioning to meaning	1994	176-179	
Liddament T	Ethics and technology curriculum	1995	160-164	

Liddament T	Design and problem-solving	1996	11-15	
Liddament T & Clare D	Learning about structures: a pilot study comparing physical and IT-based modelling materials	1994	91-96	
Liu Yu-Tung	"What" and "Where" is design creativity: a cognitive model for emergence of creative design	1996	22-27	
Lloyd M	Developing a greener technology curriculum	1993	141-146	
Lloyd M	The culture of connectedness	1994	70-73	
Lommerse M	Shifting trends in interior design careers: the graduates' story 1977 to 1998	1999	138-145	design careers, interior design, interior architecture, professional development
Lumley M G	The assessment of graded objectives in Craft, Design and Technology	1988	122-125	
Macdonald A S	GU + GSA = L + R: educating the whole: course structure for a human-centred approach in product design engineering	1995	88-92	
Macleod-Brudenell I	Teachers' confidence as a factor in addressing cultural diversity within design and technology education for young children	1996	136-142	
Makiya H	A model for topic planning	1989	70-79	
Mallatratt J	Staff development (INSET) policies to support the use of IT across the curriculum: the good news	1992	127-130	
Mankinen P & Turpeinen J	Entrepreneurship and technology education: Finnish initiatives	1999	146-151	technology education, entrepreneurship education, curriculum
Martin D J	Turning systems into artifacts (progression using electronics in design and technology?)	1989	80-84	
Martin D J & Coleman J M B	Design and technology preparation and provision - a pilot survey	1991	134-141	
Martin D J & Coleman J M B	Developing information skills and system thinking: a resource-based approach to electronic control systems	1993	104-107	
Martin M	Evaluating the work of others at key stage 4: requirements, opportunities and approaches	1993	136-140	
Martin M	Perceptions of products and applications	1995	58-62	
Martin M	Valuing products and applications	1996	28-32	

Martin M & Riggs A	Lost contexts and the tyranny of products	1999	152-157	contexts, curriculum, evaluation, policy, process-product debate, values
Martin M C	Global contexts for design and technology	1991	142-146	
Matthews A V	Engineering and education - a partnership?	1992	60-66	
McBrien R & Martin D J	An assessment of development education resources in technology: their effectiveness and some issues arising	1994	147-150	
McCardle J & Kirkham C	The challenge of utilising new technology in design education	2000	122-127	Artificial intelligence, technology integration, technology transfer, research, tertiary eduacation
McCormick R *et al*	A pilot study of children's problem-solving processes	1993	8-12	
McCormick R *et al*	Design and technology as revelation and ritual	1994	38-42	
McCormick R, Davidson M & Levinson R	Making connections: students using science understanding of electric circuits in design and technology	1995	63-67	
McNair V, Dallat J & Clarke R	Effective teaching: questioning teachers' interactions with pupils in technology and design	2000	128-133	case studies, classroom practice, design pedagogy
Mcshea J F	Design methodology - a framework for progression	1989	90-94	
Meredith H & McGuigan E	Technology for all - a curriculum development initiative in the North West TVEI LEA's	1989	85-89	
Middleton D E S	By mind and hand: the importance of manufacturing artefacts in the education of engineers	1994	156-159	
Middleton D E S	Industrially sourced design projects. Discipline renewal of teachers of technology	1995	93-98	
Mockford C & Torrens G	Students use of internet resources in the context of design and technology project work	1997	161-169	
Mockford C D	The merits of peer group review as a component in the assessment of design and project work in higher education	1994	165-175	
Mockford C D	The development and application of an analytical tool for student appraisal of design folio work	1995	165-172	

Mockford C D	The evaluation of different styles of teaching and learning in the context of design and technology education	1996	101-106	
Molwane O B	Developing technology education in Botswana	1993	118-122	
Montgomery I *et al*	Measuring appropriateness - perceived relationships between typography and form	1999	158-163	perception, graphic design, visual character, appropriateness
Morley E	Teaching cost awareness in design for manufacture	1998	99-105	
Morris T & Oliver G	Problem solving with plastics	1989	118-125	
Mulberg C	Technology for people	1988	56-62	
Mulberg C	Appropriate technology in the design and technology national curriculum	1989	95-102	
Murray J A	The relationship between "modelling" and designing and making with food as a material in design and technology	1992	37-41	
Murtough N	Linking technology education and environmental education in the South African outcomes based curriculum, at Grade 1	1998	230-236	
Nam T J & Gill S	An effective prototyping method for delivering interaction design in industrial design education	2000	134-139	prototyping, interaction design, industrial design, design tools, computer-supported design, ergonomics & design
Ndaba N N	The effects of the shift from traditional craft subjects to design and technology in Botswana	1994	109-114	
Nicholson B & Barlex D	Towards a national framework for Craft, Design and Technology in-service training	1988	159-163	
Nicholson B S	Assessing design and technology in the national curriculum	1989	103-109	
Nicholson B S	Implementing design and technology in the National Curriculum	1990	108-112	
Norman E W L	Towards the capture of design intelligence - a focus on independent learning materials and calculation software for the analysis of structures	1997	196-204	
Norman E W L & Roberts P H	The nature of learning and progression in design and technology	1992	9-14	
Oboho E O & Bolton N	Matching students' technological thinking with the demands of a	1989	110-117	

	technological curriculum			
O'Hare F	Partnerships with industry, design students practice project work with industrial partners - a case study of the learning experiences and the benefits for curriculum development	1998	106-115	
Oppenheim B	Managing change in Design and Technology	1988	52-55	
Outterside Y R	The emergence of design ability: the early years	1993	43-49	
Outterside Y R	The emergence of scientific and technological awareness in the early years	1994	4-8	
Outterside Y R	Can young children mentally rotate an image on a 3-D block and consequently make a prediction based on this mental rotation? Can they also see from another's point of view?	1996	53-58	
Owen M	Schools in control? Questions about the development of the teaching of cybernetics	1993	108-112	
Owen S & Heywood J	Transition technology in Ireland	1988	75-82	
Paechter C F	Texts, power and design and technology: the use of national curriculum documents in departmental power struggles	1993	151-154	
Papoutsakis H	Management and innovation	1995	173-181	
Parker-Rees R	Learning from play: design and technology, imagination and playful thinking	1997	20-25	
Parkinson E	The seduction of the wheel: a synthesis of research-based issues surrounding car-led construction activities of young children and current environmental trends which progressively seek to limit the impact of road traffic	1998	22-26	
Parkinson E	Aspects concerning the acquisition of a technical vocabulary in primary schools: a study of the terms "axle" and "shaft" and their use by children and teachers	1999	164-169	language, mechanisms, primary
Parkinson E	Developing an understanding of structures: experiences from primary teacher education	2000	140-146	primary, structures, teacher training, misconceptions, problem-solving, force
Passey D & Ridgway J	Coordination of technology does not equal coordination of information technology: on misperception and maladaption	1991	147-155	

Pavlova M	Concept of knowledge in technology education: cross-cultural perspective	1998	237-243	
Pavlova M & Pitt J	Technology education in Russian schools - the role of 'standards'	1998	244-251	
Pavlova M & Pitt J	A design-based approach to technology education - is it acceptable practice in Russia?	2000	147-154	design-based approach, cultural specificity, humanisation, epistemology, students' attitude, methods of teaching
Peacock L	Discourses of technology education	1997	212-216	
Peacock L M	Interplay in curriculum implementation - seeking a theoretical position	1994	103-108	
Pearson F	Cognitive style related to the design process	1988	143-149	
Pearson F	Getting design and technological cross-curricular work started	1989	126-131	
Pearson F	Liaison audit/questionnaire for national curriculum in design and technology between the primary and secondary school	1990	115-120	
Pearson F	Structuring design and technology for pupils with learning difficulties	1991	156-162	
Pedgley O	Towards a method for documenting industrial design activity from the designer's perspective	1997	217-222	
Peled A & Zur A	The Ecoanalysis workshop - rehabilitating the alienated architectural imagination	2000	155-163	design psychology, design pedagogy, design sensibility, design theory
Pereira J Q	Divergent thinking and the design process	1999	224-229	creativity, cognition, imagery, sketching and design
Phillips W, Filson A & Brown R	Managing innovation in new product development: reviewing the performance of small and medium-sized enterprises	2000	194-200	competences, new product development, innovation, technological systems
Pitt J & Pavlova M	Russia in transition: the concept and practice of technology education in schools - the programme "technology & enterprise in Russia"	1997	99-105	

Poat D R & Zanker N P	Current practice and future needs for design and technology in the secondary sector	1991	163-175	
Pratt B M	The use of sensory evaluation techniques in food product development at key stage 3 and 4 of design & technology	1994	55-59	
Price G P & Reid D J	The delivery of technology content in one-year initial teacher education partnership schemes	1993	179-183	
Price G W	Advanced supplementary design and technology examinations in the UK: criteria and strategies for curriculum development	1992	101-104	
Price G W	Equipment demand changes in the UK technology national curriculum	1994	64-68	
Price G W & Lumb S	Dyslexia-related difficulties in the development of abilities in craft, design and technology: the design of a research strategy	1991	176-180	
Price G W & Mason R	Articled teachers of technology: an evaluation of the first year of the North-West consortium programme	1991	181-186	
Ramdane K-E *et al*	Improving design education at Kanazawa Institute of Technology	2000	164-170	design engineering, education, Japan, modular resources
Ray C	Form versus content: initiatives in educational and academic publishing	1988	93-95	
Rhodes P	Abundance of information - how do designers use information	1998	132-140	
Riggs A	Teachers' personal and public beliefs about science and technology	1993	165-170	
Riggs A	The female perspective on technology	1993	148-150	
Riggs A & Dillon P J	Technology and the humanities: opportunities for educating about value issues	1992	25-27	
Riley P H	Application based studies	1989	132-140	
Ritchie R	Teachers' professional development in design and technology through action research	1995	111-115	
Robinson A G	Facilitating design & technology education for distance education students in Australia (teaching audiographically)	1994	74-79	
Roden C	Young children's learning strategies in design and technology	1995	21-27	

Rodgers P & Clarkson J	Knowledge usage in new product development (NPD)	1998	252-258	
Rogers M and Clare D	Design and technology curriculum development in ITE through partnership in local industry	1992	168-170	
Rogers M and Clare D	The process diary: developing capability within national curriculum design and technology - some initial findings	1994	22-28	
Rogers M and Clare D	Technological approaches to environmental education	1995	182-186	
Russell P, Durling D, Griffiths B & Crum G	Design guidelines - an unacceptable constraint on creativity or good design practice?	1997	140-145	
Rutland M	An analysis of a developing partnership between ITE and schools in the training of secondary D&T teachers	1996	153-160	
Rutland M	Teaching food and textiles technology in secondary schools: routes through higher education	1999	170-176	staffing, food technology, textiles technology, teacher training, higher education, courses and careers
Rutland M & Pepper L	Information communication technology (ICT) in secondary design and technology (D&T) teaching: a study of partner schools linked to a postgraduate initial teacher education (ITE) course	2000	171-179	ICT, CAD/CAM, D&T secondary, ITT, INSET
Sage J	Developing relationships between science and technology in secondary schools	1992	68-74	
Sage J & Steeg T	Linking the learning of mathematics, science and technology within key stage 4 of the National Curriculum	1993	58-64	
Samuel G C	"They can never make what they can draw" - producing a realistic, appropriate, and achievable design at Key stages 1 and 2	1991	187-194	
Santakallio E	On the development of education in technology and entrepreneurship in Finland: the KYTKE 2005 Project as an example	1998	259-265	

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Siraj-Blatchford J	Values in design and technology: beyond epistemology and ethnocentrism	1993	130-135	
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Stables K	Who are the real clients in school based design and technology projects?	1993	50-53	
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Stapley J V	Nursery rhyme - an assessment of primary technology capability across key stage 2	1994	15-21	
Stein Georgina	Improving practice in initial teacher education: assessing student perceptions of their design and technology capability	1995	116-121	
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Tsai S-T & Yang M-H	Challenges and responses: the revisions of national curriculum standard for technology education in Taiwan	1999	184-187	National Curriculum standard, technology education, Taiwan
Tseng Kuo-hung	The model of teaching practice for trainee teachers of technology at the junior high school Taiwan, ROC	1996	143-146	
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Tyers J	Personality and other attributes, qualities, abilities and opinions of some A level Design students	1988	138-142	
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Wadsworth D & Martin D J	An international educational perspective on technology and change	1992	116-125	
Walker S	How the other half lives - product design, sustainability and the human spirit	1999	237-242	aethetics, art, design philosophy, spirrituality, sustainability
Walsh I & Clement M	A collaboration leading to the introduction of an innovative medical device to the international market	2000	201-205	innovation, industrial design, collaboration, medical technology, product development, optoelectronics
Webster R D	An evaluation of mixed ability and team teaching methods for the delivery of Avon modular design and technology to all pupils in key stage 4	1993	155-164	
Welbourne-Wood S	The routines and rituals of a design and technology classroom: an ethnographic study	1999	195-199	D&T, ethnography, culture, girls, boys, teaching and learning
Welch M	Year 7 students use of three-dimensional modelling while designing and making	1997	61-67	
Welch M & Lim H S	The effect of problem type on the strategies used by novice designers	1998	75-82	
Welch M & Lim H S	Teaching sketching and its effect on the solutions produced by novice designers	1999	188-194	designing, modelling, protocol analysis, sketching
Welch M *et al*	Teaching elementary science and technology in Ontario	2000	180-185	elementary, D&T, science, professional development
Wild P	Physics or Technology? Technology or Physics? An experiment in curriculum development	1988	63-68	
Wild P	Information technology across the curriculum: some realities of implementation	1989	163-172	
Wild P & Hodgkinson K	Providing information technology competency in primary and secondary initial teacher training	1990	144-150	

Wilkinson R	Key factors relating to good practice in the teaching and learning of Key Stage 3 design and technology	1999	200-204	collaboration, problem solving, sustained motivation, successful pedagogy, quality of outcomes
Williams A	Communication in the context of design teams	1997	231-236	
Williams A & Williams P J	A project to incorporate remote collaboration into a design process for technology teacher trainees	1997	188-194	
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Willey R & Dickinson D J	Integrating manufacturing industry, and design education within a national curriculum framework	1989	173-181	
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Worsley J	Graphical Communication Design: a new subject?	1988	31-36	
Wright M & Thomson C	A comparative study between the USA and Scotland with respect to selected issues affecting implementation to elementary school technology education	1998	37-46	
Yates C	Technology across the curriculum - the Wigan project	1989	182-192	
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Yeung K-h & Chow S-c	The modular production system (MPS) an alternative approach for control technology in design and technology	1998	184-191	
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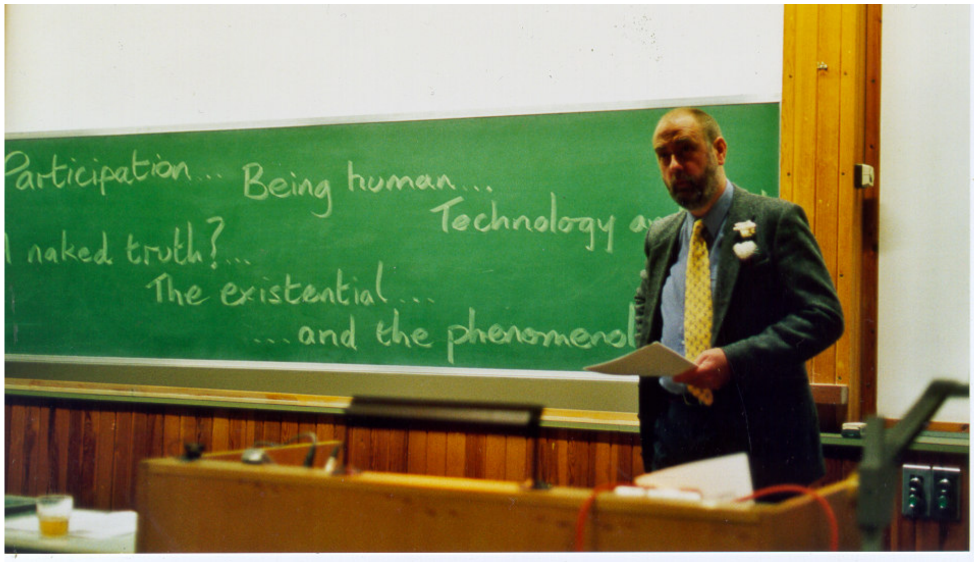
Steve Keirl



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