ON KNOWLEDGE IN ARCHITECTURE AND SCIENCE

Peter Downton
Department of Architecture and Design, RMIT University, Melbourne

SUMMARY

The central tenet of this paper is that an understanding of the relationship between the epistemologies of science and architecture should form a foundation of any investigation of the 'scientific basis of design'. This is explored here by examining accounts of science, parallels between science and architecture, and some of the means by which knowledge is (claimed) to be produced, and also by considering the use of knowledge in architecture and the production of knowledge through designing. There are both similarities and differences between the two fields. The relations of knowledge in theory (within both science and architecture) to the production of knowledge in the practice of each discipline area is considered. In both cases research is central the creation of knowledge. There are differences in the level at which research concentrates on contributing new knowledge in the two areas: at the collective level of research which can be stored and transmitted, and at the personal/individually educative level; there may also be differences in the relationship of the researcher to the knowledge which results in each case.

If schools of architecture are indeed "... (re-) embracing the scientific basis of design and investigating its relationship to the formal, cultural and artistic concepts of creating architecture", then an understanding of the relationship between the epistemologies of science and architecture should form a foundation of this investigation.

The putative 'scientific basis' carries a degree of baggage with it that requires some examination:
(1) There is an implied claim that science is good, and that it represents true knowledge (or at least in aspiring to do so provides knowledge that is more significant than other possible knowledges). For some, this amounts to a charming faith that knowledge produced by science is certain knowledge.
(2) There is the latent assertion that scientific knowledge provides the 'proper' foundation for architecture as a professional activity. This is a sub-set of the idea that proper professions rigorously apply scientific knowledge for the good of clients in the profession's area of expertise.
(3) There is an underlying feeling of inadequacy for some, who regard architecture as a deficient discipline which must automatically benefit from borrowings from its betters - in this case all-knowing science. (The symmetrically silly viewpoint exists amongst those who find science not nearly groovy enough, lacking style and generally out of fashion, who would thus avoid science as a source of inspiration wherever possible.)

Architectural practice is obviously impossible without scientific knowledge as, in its concern with the construction, operation and maintenance of buildings, architecture is dependent on knowledge concerning gravity, hydraulics, electricity, thermodynamics, materials chemistry ... the list is vast. It is a certainty that the technologies available and emerging must be drawn upon to evolve a large scale responsibly-ecological architecture. These are not aspects of the science-architecture relationship to be considered in this paper. Rather, I will explore the nature, structure and use of knowledge in each area, and the way knowledge is produced or acquired to draw out the relationship they should have in architectural education.

Knowledge and truth

Many blame or applaud Descartes for starting Western thought on its particular path to its current condition. The case against Descartes asserts that

> "Human experience, previously dripping with numen and significance, has become impoverished by rationalism, positivism and divorce of mind and body. This let slip the evils of contemporary civilisation and architectural Modernism like wars of mass destruction, ecological disaster, torture, and tower blocks." (Tabor, 1993)

Those who support Descartes, either explicitly or implicitly, can endlessly cite examples of (probably scientific) knowledge being deployed to improve our lot, our understanding of the world, and our ability to shape it to our own ends in diverse fields. This is the usually unquestioned view that we are amassing better and better knowledge of the workings of the world. In this inherited dominant view, according to Richard Rorty

> "To know is to represent accurately what is outside the mind; so to understand the possibility and nature of knowledge is to understand the way in which the mind is able to construct such representations. Philosophy's central concern is to be a general theory of representation, a theory which will divide culture up into the areas which represent reality well, those which represent it less well, and those which do not represent it at all (despite their pretence of doing so)." (Rorty, 1980:3)

Designing is a way of representing what will be or what could be. In philosophic terms it is thus often concerned with counterfactuals. 'Knowledge' of the future does not qualify as knowledge in most accounts, since they separate 'knowledge' from 'belief', where belief is stronger than mere opinion but not as strong as knowledge. They also, at least implicitly, regard knowledge as having something to do with truth. Typically, the minimum conditions for a claim to knowledge are that if you claim to know something then you at least believe it, it *is* true, and there are good reasons for believing that it is true.

Nothing, ensures that scientific knowledge is true, even if it is the very best explanation available at the time and is believed to be true. The history of science is littered with examples of what was once knowledge (or at least dominant theory) and is now a joke. (Phlogiston has joke status; ether is coyly described as 'an unnecessary assumption' in The Penguin Dictionary of Science.) But architects must make decisions; they require instrumental knowledge in the form of tools to make things happen in the way that is desired. Workability is more immediately important than truth, and truth is inevitably problematic. Rorty points out that the pragmatic philosophers have let us see truth as

> "... 'what it is better for us to believe', rather than as 'the accurate representation of reality'. Or, to put the point less provocatively, they show us that the notion of 'accurate representation' is simply an automatic and empty compliment which we pay to those beliefs which are successful in helping us do what we want to do." (Rorty, 1980: 10)

Thus do truth and instrumental knowledge go hand-in-hand. And we expect science to provide this type of knowledge, specifically through the developments and application of 'scientific method'.

The physicist's lunch

So-called scientific method can be characterised as having the following form:

(1) observation and experiment by researchers leads to the formulating of
(2) an inductive generalisation, from which
(3) an hypothesis is formed. This hypothesis is
(4) subjected to tests designed to verify it, and this process leads to
(5) the proof or disproof of the hypothesis. From this we have firmly founded
(6) scientific knowledge.

The process outlined above at first appears to describe the careful and reasonable steps the myth fosters. It also points to the two aspects of science that are often rolled into one: the aspect of theory and the aspect of experiment. The image of science involving experiment seems to predominate, but experiment is driven by theory at many levels and some science is commonly conducted in the theoretical realm - for example much that has been celebrated in the physics of quanta and cosmology.

Many questions may be asked of the simplified account of naive inductivism above, which although made more sophisticated in various ways in other descriptions by means such as the introduction of probability, remains at the heart of all accounts. A quick sample of troubling questions: What guides the observation and experiment? What are we to do in response to Popper's instruction to a class in Vienna over sixty years ago: "Take pencil and paper; carefully observe, and write down what you have observed!". (Popper, 1974: 6) What is appropriate to observe? How much of it? For how long? A 'hidden' set of theories determines what is to be observed, what will be ignored, and the manner of observation. The physicist's lunch we know is irrelevant to his experimental findings in the particle accelerator. How do we know this? Is perhaps an argument with the Institute Director more relevant? For theoretical rather than experimental physicists is the quality of lunch more important to *their* post-lunch ruminations which are not controlled by supposedly rigorous and orderly scientific protocols? How many tests verify something? Are a million confirmations necessary? Is seven satisfactory, or would ten prove the findings more? How is the quality of a test established? On whose judgement and what criteria? How nearly correct or expected must an answer be to be held to conform to the pattern of results deemed to provide confirmation? The admission that judgement is involved in the process of science attests to a greater similarity with designing than a (post-) rationalised account normally permits, since in part what is being dealt with concerns good and bad, better and worse, not issues of right and wrong.

Theories

In such contexts we are used to the explanatory functions of theory, where it is concerned with putting facts and ideas into place within a larger story. Here it is theory that connects the outcomes of experiments with the outcomes of (prior) experiments. When this cannot be accomplished, theorists' efforts are directed to seeking explanations for the anomalous findings. This kind of theory, Positive Theory in Lang's terms (Lang, 1987), can be concerned with explicit description and explanation of a range of phenomena or with the specification of procedures for acting within its domain. It is this kind of theory that upholds the image of science when viewed from architecture. But, in the last two decades or so architecture has been dominated by Normative Theories, those prescriptions for action such as manifestoes, design principles, and standards. They are expressions of ideological positions on what the world, good design, good architecture, good cities, etc. should be. Some such theories deal with practice; they describe or prescribe procedures for operating for anyone hoping to produce 'good' architecture. The overarching concern of architectural theories is with what architecture should be and what it could be. Rarely are they concerned with what it is, because its current state is conceived to be problematic and in need of the prescriptions of the theorist. Theories offer prescriptions on a wide front: the ways architecture should be practised, what it should be concerned with, and how designed things should look; they give accounts of how it is experienced and views about what it 'means'.

Generally, theory in any field (if not always particular theories) is expected to extend beyond the particular and pertain to generalised sets of circumstances. Whether a theory has been generalised from one or more particular instance, or derived by way of speculation, it is expected to have application to all circumstances within its sphere of concern and, if it is to be deemed a decent theory, to be well argued and substantiated whatever its field. But we must admit the possibility that architects are more swayed by the stylishness of the theory and who promulgates it than is desirable in (hopefully) rigorous scientific circles.

In recent decades in science, Complexity Theory (Ostwald, 1998), has continued along the path of constructing theory intended to account for what its advocates hold to be anomalous findings generated in prior paradigms. It has provided an excellent example of research being driven from pure theorising with experiments being conducted within and on computer modellings of systems abstracted from the world.

> "One of the great challenges of contemporary science is to trace the mix of simplicity and complexity, regularity and randomness, order and disorder up the ladder from elementary particle physics and cosmology to the realm of complex adaptive systems." (Gell-Mann, 1994: 119-120)

Architecture enters in at this point; it is commissioned by institutions that are complex adaptive systems and it is frequently required to house such systems. (Downton, 1995) That it is well up the chain of complexity seems to contribute to the idea of it being a 'user' of data from lower in the chain .

Refuting conjectures

From the nineteen twenties onwards various philosophers of science have given accounts of science which argue that the view of incremental progressive knowledge as obtaining in the standard description of Scientific Method is erroneous, and that at base there is very little certainty given the lack of clarity and consistency revealed by questions such as those put above.

In addressing such issues, Popper argued (Popper, 1972) that the real pattern of scientific inquiry stems from the embedding of facts within theories. There are no facts which are independent of theories within which they are facts. He says that scientists start with

(1) a problem (usually a set of facts which do not fit within existing theories properly). This is a more realistic account than the 'observation and experiment' of the Scientific Method outline above as it admits that there is always precedent - we are in the midst of a process, not at its beginning. As the result of thought about the problem
(2) a theoretical conjecture is put forward which offers a proposed solution, and from this are abstracted
(3) testable propositions. Such propositions do not have to be tested, rather they must be cast in a form which is testable in principle. It is these propositions which are *scientific statements*, and their inherent testability is what distinguishes them from non-scientific statements such as those made by religions. (Astrologers provide another favourite example of non-testable, and thus non-scientific statements). Given appropriate means, scientific statements are usually subject to
(4) tests designed to refute them (typically experiments or observations) which are, of course, derived from within the same system as the propositions under test. Such tests can never provide proof, only disproof. The most successful scientific statements are those which have many times received confirmation and have *yet* to be disproved. Finally science and scientists must
(5) select between competing theories which explain the same phenomena.

This account does not address one common activity of science - exploration, the seeking of new materials perhaps, the (often accidental) discovery of a biologically useful new substance. This kind of inquiry looks much more like designing in structure; it is focussed on the production of something new. It is concerned with moving away from the existing, the known, through intentional actions to arrive at an as yet unknown, but desired, outcome. And, like designing, it is alert to the fortuitous; it can profit from the accidental and the misinterpreted.

It is argued in accounts which have used conjecture and refutation as a description of designing (Hillier, Musgrove & O'Sullivan, 1972) that designers can, or do, put forward a proposal (conjecture) which is then subjected to a process of testing (refuting) and modified to satisfy the tests.

What this offers is a paralleling of the structures of these two ways of producing knowledge. Both are putting forward a proposition of the way something may be and then examining it by testing to check whether it 'works', but the analogy is rather inexact: science is presumably putting forward an explanation of some set of circumstances or operations; architecture is putting forward ideas about the way things can be brought into being. Science tests to see if the account matches with 'reality'; architecture tests to see if the proposal satisfies the criteria for judgement that have been set up for the test. These criteria are established by similar conjectural means to the proposal to be tested. Something similar happens in science in that what serves as a test is not unequivocal.

Three tales about science told by an architect

The three well-known accounts of science below consider its character as a whole more than they consider the production of knowledge. Again, they can be examined to find what light they cast on the nature of knowledge in the two areas. First, in the account by Thomas Kuhn science is presented as a social enterprise (Kuhn, 1970), making it more overtly similar to architecture as a cultural sphere than any purely epistemological account achieves. He argued that (a) science evolves through comparatively stable periods of 'normal science' which are followed by 'revolutions' - periods when radical proposals start to appear more fruitful as explanations than the explanations of the dominant paradigms of normal science. In time, as more scientists adopt the new paradigm its tenets become the new orthodoxy. In turn there will be another period of crisis and revolution. The 'over-throw' of classical physics by quantum mechanics is the best known example of this. (McCormmach, 1982) The model of fundamental changes in disciplinary matrices proved attractive for those attempting an account of the Postmodern 'revolution' in design disciplines. The question that must be addressed if the Kuhnian account is to be applied to architecture is the degree to which the two orthodoxies are in fact commensurate. That is, does the account of the adoption of a new suite of explanations in science serve as a model for the adoption of the post-modern view and a raft of stylistic devices and concerns in architecture? Maybe reversing the direction of application of the model might be more illuminating and allow a questioning of whether explanatory paradigms are style-driven in science and whether elements of feeling and fashion (familiar to designers) intrude into what is painted as an entirely rational pursuit.

Scientific theories are conceived of by Imre Lakatos as structured research programs, each with a central core of basic assumptions which cannot be rejected or modified without abandoning the program (Lakatos, 1970). There is also a 'protective belt' of statements, auxiliary hypotheses, etc. around each core. Coupled with these there is what he terms a positive heuristic of guidelines for the development of the research program. These ancillary parts are more easily sacrificed than the core propositions. This protective belt is also the realm where rather ad hoc assumptions and hypotheses are placed to offer explanations for why the experimental results do not quite accord with those predicted by theory. At any given time, according to Lakatos, a program may be static, degenerating or progressing. We might see modernism in design as a project which degenerated, but which is, in some quarters, again progressive. Alternatively it could probably be argued by assembling the right examples that the core of Modernism was maintained while the protective belt changed to allow Postmodernism.

The choice of this view over the Kuhnian one forms part of a different analysis of Postmodernism - wherein it is held to be a subset of Modernism not a successor to it. With time, the dominant history will adopt a position on which is the case.

In the third account, science is seen, by Paul Feyerabend, as "... an essentially anarchistic enterprise: theoretical anarchism is more humanitarian and more likely to encourage progress than its law-and-order alternatives. ... The only principle that does not inhibit science is: *anything goes*." (Feyerabend, 1975:10) He asks why new models in science should have to accord with existing ones whose only claim to primacy is that they came first? Why should there not be rival explanations? He argues that such alternative explanations are both common and powerful. Different systems of explanation provide coherent accounts of their universes of discourse within their own system. The tests of scientific knowledge are simply that. They are only 'better' within the belief structures of science. Science is, in essence, another myth - one of a number of ways of thinking about the world, not unarguably the best. The choice of explanation should be left to the individual. The church and the state have been separated in most places, why not, Feyerabend asks, separate the religion of science from the state too?

Because the accounts from Kuhn, Lakatos and Feyerabend offer insights into the overall structure and culture of science they may serve as models for examining architecture as a discipline and profession. Knowledge in architecture and other disciplines is deemed to have moved beyond the modern to the postmodern and thus to be devoid of any possibility of a metamythical structure. On this account, Modernism is constructed as a time of a singular guiding myth, and is decried. And yet, perhaps through nostalgia for past certainties, there has been renewed interest in the buildings of the golden era of revolutionary myth-forging in design - the time of Modernist manifestoes. Perhaps designers long for certainties, some cries about which to rally for collective comfort. The message of Postmodernism was that the certainties were gone - there was revolution! For those attempting explanation of this by using the Kuhnian account and mapping the change from one paradigm (Modernism) to another dominant disciplinary matrix (Postmodernism), the concept that architecture can be modelled as following science seems implicitly to be held as significant - an oddly modernist notion. That Kuhn, rather than the inherently Postmodernist philosopher Feyerabend, should have been followed, is a surprise, for whereas Kuhn's account suggests the replacement of one dominant myth by another, and is thus hard to reconcile with the Postmodernist denial of the possibility of a single metamyth, Feyerabend argues for a pluralism of explanatory models under a banner of epistemological anarchy. On reflection, it seems that if there is a resurgence of interest in science within architecture this is part of the rediscovery of interest in Modernism and modernist projects.

Three worlds, a fourth tale

Karl Popper's account of the three worlds positions knowledge in a manner of interest to design disciplines:

World 1 is *the world of material things*, and
World 2 is the *world of minds*.
These are often distinguished by philosophers as the objective world and the world of subjective experience. To this Popper adds

World 3, *the world of objective knowledge:*
This is the knowledge of science, language, philosophy, of art, and human institutions. Once created, the structures in this world are independent of their creators and may exist without a knowing subject, preserved in libraries or buried texts, but always encoded by some World 1 artefact.

Examination of this construct suggests that design activities such as architecture necessarily bridge the three worlds. Design ideas about vacuum cleaners, buildings, city squares and other designed physical objects belong to World 3. This would appear to be where a design exists although it is represented in World 1 via drawings, models, etc. The outcomes of designing, once made manifest, are World 1 entities: maybe the very objects vacuum cleaner, building and city square. Experience of these objects takes place in World 2. The growth of the Internet seems to stretch this proposition. Massive amounts of objective knowledge are stored in computers with a certain sense of ethereality and fluidity not in keeping with Popper's examples of World 1 objects.

Research knowledge and design knowing

The central scientific notions from experimental research of replicability of outcomes and consistency in their interpretation, does not have a full parallel in architecture. In the technical domains of architecture, knowledge must be replicable, but in the artistic realm architecture expects anything but replicability. This is a source of disquiet for practitioners who attempt to hold to a 'Technical Rationality' model (Schön, 1983) of the profession of architecture.

Architectural knowledge could not sensibly exist without its application in the world. To a large extent at least, the application of architectural knowledge is professionalised and the characteristics of professions are more-or-less applicable to architecture, which leads to the idea of the rigorous use of the appropriate instrumental knowledge available from scientific sources. The essential properties of the knowledge base of a profession are that it "... is specialised, firmly bound, scientific, and standardised". (Schön, 1983:23)

Architecture, therefore, is not a particularly good example of a profession. But should this account of a profession be applied to architecture? Is it a worthwhile account of *any* profession? The physical and social world has proved to be far too complex to be dealt with by such a singular and simple-minded model. The professions have been constantly criticised over the last forty years or so. The 'rational' application of technical knowledge is often 'irrationally' confronted by people who think the wrong problems are being solved, who do not want the nuclear power plant, the freeway, the factory, the mine, or the new building. This dominant 'Technical Rationality' view of professional knowledge naturally pervades those professional educations where the supposed scientific knowledge-base is taught prior to teaching the skills necessary to apply the knowledge to the area with which the profession deals. It has grown up with the positivist and particulate view of science that has developed over the last few centuries. In the case of architecture most courses opt for paralleling the acquisition of design skills with the knowledge utilised from other disciplines that might be applied by designers. In this manner architects get some sense of calling on knowledge as needed, a sense that knowledge acquisition is driven by purpose, which is similar in structure to the idea in science that observations to establish facts are theory-dependant.

The implied model of design as a 'user' of knowledge does not address the knowing of design that is necessary for someone to effectively design, nor does it consider the knowledge brought into being through designing. The similarity of scientific inquiry to design inquiry is neither perceived or investigated. Research is portrayed as an elevated activity. Designers remain substantially trapped by the insidious process of hierarchisation set up to enshrine and defend the dominant position of scientific knowledge and the culture of traditional research. Tertiary education provides an annoyingly excellent example of this: government funds for research go to disciplines that do research and report its outcomes in traditionally prescribed ways. A limited degree of new understanding is happening; in my home institution, RMIT University, there is a broadening awareness that research is not only done in hard- and social-science departments. Credit for studio-based research in design disciplines is possible; we offer Masters degrees (van Schaik, 1993 & 1995) and PhDs under a university regulation covering research degrees, but these regulations are written to allow, and specify the requirements for, these degrees to be undertaken by project work in areas such as architecture, interior design, industrial design, landscape architecture, art, etc. Design as research is admitted. This does nothing to improve government funding, but we do not feel entirely unloved.

It is held that the purpose of research is to produce knowledge. This can be at the individual or the collective level. New knowledge for an individual is important and obviously what we ask education to accomplish, but it is new knowledge for a collective that is celebrated as knowledge, as that which can be stored and transmitted to others. Research undertakings (such as doctorates) are asked to make, or attempt to make, contributions to the disciplinary knowledge of their field. This is a contribution to collective knowledge. Research projects are criticised, funded or rejected on the basis of their ability to produce this level of knowledge. Such assessments employ a number of hidden assumptions about what knowledge *is*, and whether different kinds of knowledge are somehow 'better' than others. Assessments are thus truly conservative - such conservatism serving to exclude the chaff of non-knowledge as well (sometimes) as the speculatively new and challenging. Such assessments often hinge on repeatability as a measure of reliability. Knowledge is mostly required to be 'scientific' in such circumstances, but the nature and worth of so-called scientific knowledge typically goes unquestioned because science provides the current dominant paradigm. If criticised, a true believer can airily point at the application of scientific knowledge by technological pursuits (architecture amongst them) and mutter the incantation 'progress' to carry the day. 'Science', or at least the scientific approach, is well entrenched and remains inviolate within our major secular institutions. Most disciplines and professions have been at pains to show that they are science-like, for this way lies respect and funding. They do not attempt to show that the scientific model is relevant to them. Questioning and/or aberrant behaviours might reduce their access to financial and intellectual capital.

Design has been painted as another kind of activity from inquiry: a user of knowledge rather than a producer of knowledge. And clearly all designing activities call on various kinds of knowledge, but they also produce some knowing on the part of designers. Something is invented or created as the outcome of designing, and this 'something' *is* knowledge. Designing as an activity, a process, can be seen as a means of inquiring - about specific circumstances always and generalities sometimes. A contribution to knowledge through the research of designing is a contribution to the knowledge of an individual or small collective; it does not have the characteristics of contribution to collective knowledge considered above. It is a learning process undertaken by the designer. Often it involves novel uses of the already known. The knowledge produced is embodied in the architectural outcome. Works of architecture store this knowledge over lengthy periods of time, so the criteria of storage and transmission are similar to that required of scientific research knowledge that overtly contributes at the collective level. The exemplary characteristic of the canon attests to such storage; it is from the canon that we learn the knowledge embodied by others. (Downton, 1998)

In testing, experimenting, and investigating what is going on in an effort to achieve a desired end each designer is conducting research. It is perhaps personal. It may not be repeatable in the sense of producing the same 'findings' if carried out by another person. It can be ill-defined, and inadequate; or it can be refined, honed, and conducted with rigour in an effort to truly test the current horizons of knowledge and understanding. In critical arenas such as architecture schools, design research is subjected to peer group scrutiny and is expected to be convincing against appropriate criteria in a manner similar to any other research.

Because much of the knowledge used to make judgements of quality and value seems to be internalised by designers they are open to accusations of operating mysteriously or whimsically or relying on so-called intuition. Perhaps they encourage this, but there are few sustained attempts to give any sort of account of the thinking processes involved in designing, and they are all after the event. We do not know, except through difficult self-interrogation, how architects make actual design decisions. What is mostly available are cleaned-up post-rationalisations of design processes similar in character to those presented as representations of scientific methodologies. Study of architects' work processes through their drawings and via interview casts some light on how design is done. (Herbert, 1993 & Steele, 1994) Is there something that distinguishes design(er's) decisions from other kinds of decision? Or are they a particular part of the spectrum of human decision making?

The designing person

In addition to any knowledge imported from or originating in another discipline, there is a kind of design practice knowledge necessary to the making of architecture or any designed object. This practice knowledge is shaped and prescribed by institutional forces, by convention, myth and aspiration. Practice knowledge serves reality as an end; the outcome of its application is the material. Designing is a way of knowing. For designers it is a path to understanding and to selfhood.

Consider Strawson's account of personhood where he argues that we can identify a class of predicates - P-predicates - which apply to persons. Whilst 'persons' as a concept involves predicating physical characteristics, location, etc., P-predicates "... imply the possession of consciousness on the part of that to which they are ascribed". (Strawson, 1959:105) And it is an essential characteristic of them "... that they have both first-person and third-person ascriptive uses, that they are both self-ascribable otherwise than on the basis of observation of the behaviour of the subject of them, and other-ascribable on the basis of behaviour criteria". (Strawson, 1959:108) According to this view, a person must first be able to recognise persons in his or her environment, ie, be able to ascribe P-predicates in the third-person, prior to the recognition of the self as a person. The possibility of first-person ascriptions arises from this recognition. Applying this to architects we might determine predicates ascribable to them, A-predicates, and substitute into the appropriate sentences above to obtain the following: 'An architect must first be able to recognise architects in his or her own environment, ie be able to ascribe A-predicates in the third-person, prior to the recognition of the self as an architect. The possibility of first-person ascriptions arises from this recognition'. This is the initial mechanism of role-modelling which plays such a large part in all forms of education - that of architectural designers being no exception. Once one conceives of oneself as being an 'x' this shapes and colours one's relations with the world. If designers, for instance, are deemed to dress or behave in a certain fashion, then self-ascription of designer-hood often leads to similar dressing or behaviour. Such roles are not likely to be unique; rather each human has an ensemble of roles making-up a total personhood. And perhaps the term 'person' is best seen as an embracing term encompassing a host of overlapping concepts such as characters, figures, persons, souls, minds, selves, individuals, and presences. (Rorty, 1976:302). These 'entities' are both defined by and define the roles they can play. They are at once self-defined and other-defined, but for present purposes the effort to be self-defining is of principal concern.

Defining oneself as an architect means that one is, to support this self-ascription of A-predicates, prepared to do what architects do or at least prepared to attempt to do so. That is, generate and implement acts and actions intended to create desired outcomes. Desire is not a concept normally associated with something as orderly as science is presented to be, but 'desired' does describe the hoped-for ends of either architectural or scientific processes. I have argued elsewhere (Downton, 1983) that all design-like activities, ie those concerned with changing the existing conditions of one's world to (hopefully) a desired set, are part of the spectrum of activities under the umbrella of human actions concerned with endeavouring to establish and maintain appropriate relations between people and their environments. This renders it easier to describe science as design-like than it is to force design to look like any typical model of science. Glanville (1998) makes a version of this argument when he contends that the doing of science as experiment or theory is a restricted form of design, where design is taken to have the form of a conversation between the designer and her material. A particular attraction of this model is that it effects a reversal of the norm: design is dominant; science is cast in the subservient role.

By examining the structure and use of knowledge in architecture it becomes clear that design knowledge is produced through inquiry, that the process is similar to the production of science-based knowledge, and there is thus a similarity of epistemologies. The value of this way of seeing the two domains is thus two-fold: most significantly it serves to clarify our knowledge and understanding of the fields, but the reversal has importance too, since for architects it may aid self-esteem by removing the cringe of inferiority, the certainty that science is better than architecture because its paradigm is on a pedestal erected, no doubt, by science with the aid of an assortment of all-conquering technologies.

Comparison of the two epistemologies

The cyclically popular subject/object distinction draws together some of the themes above to enable an encapsulating speculation on the relationship between the epistemologies of architecture and science. There are several senses in which we can speak of the 'object' of knowledge - what is the purpose of knowledge (in general or with reference to particular knowledge), what are the 'things' or objects that can be known (in some circumstance), what is it that is known about a particular object which is the focus of some knowledge. The 'subject' of knowledge might refer to the topic of knowledge, or its use might be similar to the term in the 'subject of the sentence', where it is part of a system which is operated upon.

Perhaps the most interesting sense is to consider the architect as the subject of architectural (design) knowledge and to be clear that design knowledge is personal knowledge, that it is brought into being by a person, and held and employed by a person. Does this help to distinguish between the knowledge which results from 'traditional' research which is concerned with finding out about objects and relations between them (and also extends to treating people as objects in behavioural sciences), and design knowledge which is immanent in its subject - an architect? Architectural knowledge is thus more properly described as 'knowing', as process-like and active. But all knowledge can be described in this way, because by 'all knowledge' we mean human knowledge, not what dogs and dugongs know. The only knowledge without an apparent knowing subject, Popper's 'objective knowledge' had a prior knowing subject to enable it to be encoded in a World 1 artefact.

My presumption is that 'the scientific basis of design' implies that architecture should be science-like. But real-world science is more like architecture than architecture can be like science. Put simply and therefore somewhat inaccurately the explorations of this paper suggest that:

- as part of the total spectrum of human knowledge, science and architecture share much, and architecture clearly makes use of large amounts of knowledge generated within the various sciences;
- within the confines of each field knowledge has a different character and structure;
- the use of knowledge in the two areas has both similarities and differences;
- the production of knowledge is similar in both fields - they are not set apart from one another by the activity of research.

Consideration of the relationships of scientific knowledge and architectural knowledge as explored in this paper would lead schools of architecture to educational programs where architecture is not cast as dependant on scientific knowledge, but as another way of inquiring about and changing the world.

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