Keynote paper: Science and technology context of architecture

Architecture, science and technology

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ABSTRACT: The aim of this paper is to examine the relationship of architectural design to science and technology. The intention is to go back to first principles (although not quite to Adam and Eve). This relationship – I suggest – is determined by the mode of thinking of the designer, hence I must have a brief look at the brain/mind relation and at some relevant parts of philosophy. Then I propose to look at design methods and theory, followed by an attempt to define and compare art and science. That should enable me to look at architecture and architectural education. This – I hope – is in the true spirit of architects, who like to dabble in dozens of different disciplines.

Conference theme: Science and technology
Keywords: mind and brain, design theory, art and science, education

INTRODUCTION

Two bits of anecdotal evidence may be useful to start this paper with; the first one is hearsay, the second is personal experience.

(i) In the mid-1930s the ophthalmology department of the university in Budapest learnt that there was an old man in a remote village who operated cataracts of the eye with his penknife. The professor with a couple of senior students travelled to this village and were quite amazed when witnessing such an operation. The old man became a celebrity. They took him to their school and showed him the structure of the eye and current surgical techniques. Their intention was to improve his skills, but it backfired. Having learnt a little about the delicate intricacies of the eye, the old man didn’t dare to touch another human eye.

(ii) My father, who was an architect, founded the Hungarian equivalent of the Werkbund (Magyar Műhely Szővetség), but he was also an accomplished painter, and was delighted with my drawings when I was 2 – 3 years old and entered a few of them in children’s art competitions, with some success. Later, my grandfather, who was a civil engineer, by then retired, and lived with us, had nothing better to do, but teaching me to read and write and also some arithmetic and geometry. He got me a pair of small set-squares and a compass, and I spent long hours doing triangles and polygons. At the age of five I could prove Pythagoras. My father was furious with his father, that he “ruined the boy’s artistic talents”. Later, in my early teens, (when I said I want to be an architect), over several summer holidays he sent me to work in various workshops for several weeks a time (following the Bauhaus idea of the unity of designing and making), such as a joinery shop, or to a steel fabricator, as he had put it “to get a feel for materials”.

To me, both items above have the same message: one can function and operate (not just cataract) quite well on an intuitive basis or perform actions learnt by training or imitation without any relevant “knowledge-base”, without any scientific understanding of the process. A little knowledge is worse than no knowledge. It may suffocate the instinctive, without providing an adequate rational basis for action. The question is how to preserve the ‘intuitive’ abilities but also have sufficient knowledge and be capable of scientific/analytical thinking.

1. BRAIN AND ‘MIND’

Bogen (1963) and many others distinguish two sets of functions for which the two hemispheres of our cerebral cortex are responsible, as summarised in Table 1 below.

In the early 1930s we did not have this left-brain / right-brain distinction, but my father clearly saw that my instinctive/imitative skill of using crayons was stifled by the set-squares and analytical thinking imbued by grandpa, but then he wanted to give me an intuitive ‘feel’ for materials.

What are these brain-processes and how do they relate to architecture?

With apologies to philosophers and brain scientists I will look into several relevant fields: how the brain works, the philosophy of science, design theory as well as education, and I hope I will arrive back at the title subject. The topics are a very personal selection, my knowledge in these fields is quite sketchy, but perhaps sufficient to gel and make a satisfactory overall view.

Table 1: Functions controlled by the left and right brain hemispheres

<table>
<thead>
<tr>
<th>LEFT (dominant)</th>
<th>RIGHT (recessive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>propositionizing</td>
<td>visual imagery</td>
</tr>
<tr>
<td>linguistic</td>
<td>visual and kinaesthetic</td>
</tr>
<tr>
<td>storage</td>
<td>visual, imaginative</td>
</tr>
<tr>
<td>symbolic, propositional</td>
<td>education: correlates</td>
</tr>
<tr>
<td>education: relations</td>
<td>perceptual, non-verbal</td>
</tr>
<tr>
<td>verbal</td>
<td>diffuse</td>
</tr>
<tr>
<td>discrete</td>
<td>visuo-spatial</td>
</tr>
<tr>
<td>symbolic</td>
<td>logical</td>
</tr>
<tr>
<td>logical</td>
<td>pre-verbal</td>
</tr>
<tr>
<td>analytic</td>
<td>synthetic perceptual</td>
</tr>
</tbody>
</table>

(The right brain is called ‘recessive’ as it more resembles the sub-human primate brain and is more closely connected to sub-cortical centres of emotion.)

Torey (1999) recognises that hemispheric specialisation was a crucial step in the development of consciousness.
as well as language, that distinguishes us from the apes. He
further develops this theme and suggests the mechanism that I attempt to outline as follows:

sensory inputs arrive at the right side (e.g. hearing and
visual areas of the brain are now well identified), these
form percepts, which are transmitted to the left side,
where word-percepts (concepts) are formed and labelled
by words (denotation). These are organised, combined and
re-combined and formed into endograms: cortical
maps, including audio-, visual- and somato-sensory
attributes (connotation). These can be accessed,
categorised and handled by language. Language and
thinking are inseparable. Indeed thinking was able to
develop only with the help of language (and vice-versa).
We can reflect on these endograms (awareness) and
integrate the results of such reflection into the endogram
itself. Furthermore, we can record this continuous self-
management. Speech and motor functions are also handled
by the left-brain.

Brain is the only materially existing entity: mind denotes
a set of brain functions and as such, it is a useful
concept. Spirit is an even more abstract (and poetic)
notion, denoting some right-brain functions. He, however,
suggests that mind has its own neural network, which
allows language-assisted integrations. A huge body of
such integrations is built up and consciousness can
direct attention to selected areas, as it were: illuminating
one portion of the large “unconscious” area outside the
current focus.

Awareness and consciousness result from the complex
interactions of the two hemispheres, through the
connecting corpus callosum. It is attentional oscillation
between the two hemispheres that avoids the stimulus-
bound and response-compulsive limitations (as Skinner’s
cats) and allows initiative. Actions can be initiated by non-
conscious brain processes but the mind would have a
control, even a power of veto.

An interesting example (from the point-of-view of
learning) is training in sports. In tennis, for example, the
essential development is to create neural pathways
between visual perception of the ball coming towards me
and the motor response. The tennis court is some 24 m
long. If the ball’s fly-path is (say) 20 m and its speed is
20 m/s (≈ 72 km/h) and it can be much faster, it will take
1 s to reach me. There is no time to consciously analyse
the ball’s fly-path, to predict where it will be in 1 s and
place myself in the right position, even swing my racquet
to meet the ball in flight, with the right direction and
angle, to drive it back to the opponent’s court, preferably
the furthest away from him or her. The normal time from
perception through awareness, to reaction (Libet, 1990,
as quoted by Torey, 1999) is some 400 – 500 ms, and
that does not include the muscular response and
physical body movement. “Training” can reduce that to
less than half. It is suggested that training prompts the
creation of appropriate neural paths, perhaps even
creating new ‘hard wired’ connections. The process is often
referred to as ‘innervation’. Certain hard-wired pathways
exist at birth, but most are grown in infancy and early
childhood, at a rate reducing with age. Hence such
training is more effective at a young age than later in life.

The same process occurs in learning to drive. The
learner’s response is initially very slow. (S)he
concentrates on the timing of clutch a gear-shift
operation whilst also steering. It may take seconds to
notice another car approaching, to devise the
appropriate response and execute that response.
The experienced driver in heavy, fast and complex traffic will use a
well-developed pattern recognition skill, and in full
knowledge what the driven vehicle can do, will

automatically do the right thing. At least it appears to be
automatic, as the driver has the necessary innervation,
obviating the need for conscious awareness of the
details and rational analysis.

Whilst Torey is deeply analytical, Koestler (1964)
operates at the surface level of phenomena. In
examin creativity he suggests an inherent similarity of
such creativity in science, art and humour. At a given
time we are thinking, talking, operating in one particular
context, a plane or a matrix (a ‘universe of discourse’),
with its own rules, relationships and conventions (Torey’s
illuminated area?). The “act of creation”, the creative
spark inseparable. In unexpected connection is made
between different such matrices and he calls this
bisociation.

In discussing science he brings up the example of
Archimedes, who connected the problem of determining
the volume of an elaborate and complex shape (a crown)
with his own taking a bath. The sudden spark, the
bisociation between his bath-routine and the physical
problem is what he calls the Eureka process. Logical
thinking (a left-brain activity) can prepare the ground
within a given (or several parallel) such frames of
reference, -- as it were -- charge the condensers to a
potential that may produce a spark. The creative spark,
even in science, may come as a sudden unexpected
insight or intuition, which may be Koestler’s bisociation.
This is the trigger, but the left brain must be ready for it
and be able to make use of it. In this case clearly the
right brain takes the initiative, to which the left brain
is subservient. Very often this is the discovery of an
analogy, which no-one saw before.

He gives several examples in humour, such as: The
marquis, who has a palace on the market square, arrives
home unexpectedly and finds his wife in bed with the
bishop. He looks at the surprised couple for a while, then
he goes to the balcony and starts blessing the crowd
outside. When this is queried by the bishop, his answer
is: ‘if you do my job, I do yours’. Bisociation occurs
between the two normally unrelated, but otherwise quite
logical frames of reference, which look at the same thing
from two different points-of-view...

The same kind of bisociation is also the key to most art,
both in the creation and in the enjoyment of the product.
It gives an internal tension, inducing the viewer to switch
attention from one level of thought to another. He gives
the example of Rembrandt’s flayed ox: at one level it is a
repulsive, disgusting object, but one can forget the
subject and enjoy the beauty of the patterns of light,
shadow and colour. This deliberate juxtaposition by the
painter of two frames of reference is -- again --
bisociation. Art originates in sympathetic magic
(essentially a right-brain activity), its basis is much more
ancient, emotional rather than rational, but today it is also
the product of hemispherical interaction.

Koestler suggests that the scientist as well as the artist
are equally dependent on such bisociation, on their
intuitions as well as rational thinking and I wonder if this
proposition is the same as Torey’s ‘hemispherical
interaction’.

2. PHILOSOPHY

In design theory the basic analysis-synthesis-evaluation
schema was dominant for several decades. This is akin
to the naive view of science, of scientific method, which
originated with Bacon (1620) and Descartes (1635),
whereby empirical data collection, followed by analysis
and inductive reasoning will result in making a
hypothesis which is then subjected to verification.
Popper (1972) concentrates on the last of these: verification or falsification. He recognises the method of trial-and-error, or conjectures-and-refutations as crucial to science. In his view proven scientific knowledge does not exist. There is no such thing as absolute proof. Bold conjectures are necessary even if most are subsequently disproved. He turns the argument around and suggests that if a statement or proposition cannot be disproved, it is not scientific. Certainty may be replaced by probability. In his view science is permanent revolution. Commitment (to any fixed view) is no more than belief; it is not only like wearing blinkers, but it is criminal.

This is anathema to Kuhn (1962), who sees a slow development in ‘normal’ science, within the established and accepted framework, occasionally, at a crisis point, interrupted by a revolution, a paradigm change. The notion is similar to the Hegelian dialectics: slow quantitative changes accumulate over an extended period, then burst into a large qualitative change.

My own footnote to the science philosophy of the second half of the 20th century is that although it is fashionable to follow the dogmatic ‘ falsificationism’ and say that Einstein disproved Newton or that modern geometry disproved (falsified) Euclid, I suggest that this is an arrogant and narrow-minded view. This is throwing out the baby with the bathwater. Only the exclusivity, comprehensive or absolute validity of Euclid or Newton have been disproved, creating a broader view, an enlarged frame of reference. For the stated frame of reference (as in terms of the then available observed evidence) Euclid or Newton are just as valid today as before Gauss or Boltay and Einstein. This view is well recognised by Lakatos (1970): a theory may be valid within a given context.

How does this all relate to design theory?

3. DESIGN THEORY

The study of systematic design methods was very popular in the 1960s and 70s, witnessed by successive conferences on the subject: Oxford (1963), Birmingham (1965), Portsmouth (1968) and Cambridge, Mass. (1970). Alexander (1964), Gregory (1986), Christopher Jones (1970), Broadbent (1973) and Wade (1977) made significant contributions. Most of these are based on the analysis-synthesis-verification sequence. Rittel (1972) suggests that 1972 was the beginning of the “second generation” methods. He urges the cooperation of the architect with the client. He recognises the “symmetry of ignorance” as well as the argumentative nature of the process, which should be transparent and documented. All these are well reviewed by Heath (1984) and he suggests that there is no ONE method for design. The method is dictated by the social nature of the task, and he distinguishes three main groups of such tasks:
- commodity buildings (determined by their function)
- symbolic buildings (where their significance is dominant)
- systems buildings (governed by the system to be accommodated).

Such studies went out of fashion by the early 1980s. Practising architects considered it as mental masturbation of academics who have nothing better to do. “Those who can, do”. However even as an academic discipline it ran out of steam. The last significant contribution (in my view) was Lawson’s book (1980): “How designers think”, although he is no longer concerned with method, rather with design thinking and philosophies. It is more explanatory of practice than postulating methodologies. He contends that ‘design’ is a skill, a skill of thinking, developed by practice (building neural paths between the two hemispheres ?) but it must have a knowledge-base. Both Ryle (1949) and Bartlett (1958) consider thought as a matter if skill. De Bono (1967) suggests that in education the development of this skill of thinking is more important than “to be stuffed with facts”.

Schön (1983) is also concerned with design thinking, but goes further in analysing architectural practice. He suggests the “displacement of concepts” as the first step in the creative process: the intuitive perception of analogies. This is very similar to Koestler’s bisociation theory. De Bono (1970) was already pointing in that direction with his “lateral thinking” and even earlier Osborn (1963) was suggesting this direction in thinking with his “brainstorming” processes.

Bamford (2002) replaces the analysis-synthesis (A/S) schema with the Popperian conjecture-analysis (C/A) sequence. Analysis itself must be directed by some conjecture (to select what is to be analysed) and – in the light of the foregoing this is likely to be a right-brain initiated process. The left brain seems to have its main role in the subsequent analysis, review or attempted refutation. Schön’s ‘reflection in action’ fits well with this C/A proposition. Hillier (1996) refers to this C/A as ‘conjecture-test’ and acknowledges that thereby science is led by intuition and imagination.

4. ART AND SCIENCE

The primary meaning of the word art is ‘skill’, but it is extended to mean the application of such skill to “subjects of taste (poetry, music)” or to the arts of “imitation and design (painting, architecture)”, but also “the practical application of any science” (the Shorter Oxford Dictionary, 1973). Herbert Read (1931) uses the word primarily for ‘plastic’ or ‘visual’ arts, but concedes that literature and music should be included. He suggests that the purpose of art is the communication of feeling and draws a sharp boundary between art and beauty. Not all that is beautiful is art and not all art is beautiful.

Feelings and emotions can be very powerful in influencing human behaviour, can influence or even override reason and strongly influencing art. Art can be considered as communication from emotion to emotion. When I am in a foul mood, a Miro painting can cheer me up. The painter’s sense of humour is infectious. I cannot explain why, but some other abstract art does not affect me, is not on my wavelength, my only response can be rational.

In Schopenhauer’s (1948) view music alone has the abstract quality to which all arts aspire. Architecture has the most utilitarian content and is most bound by materials. Indeed one can compile a list of arts in the order of being bound by materials and utility, such as: music – poetry – literature – theatre – painting – sculpture – (industrial– and product–) design – architecture. This order also implies an increasing dependence on technology.

Both Read and Roger Fry (1920) consider art and beauty as social phenomena and historically changing. Both are culture-dependent and reflect current thinking. My question is: whose thinking? Is it art for art’s sake (L’art pour l’art), is it architecture for architects (and perhaps only the avant garde of architects), or is it for the ‘people’? Do we follow the Frank Lloyd Wright edict to “give them what they cannot even think they could have”? Is this ‘current thinking’ really changing as fast as architectural fashions are?

Science is defined as knowledge acquired by study, or
“a branch of study, a connected body of demonstrated truths, or observed facts systematically classified ... brought under general laws” (Shorter Oxford Dictionary).

In plain English it is organised knowledge, our mental picture of the world and of how it works. How such knowledge is obtained is the subject of epistemology, a branch of philosophy discussed above. For Kant (1933) the *ding-an-sich* (thing-in-itself) is not knowable, reason deals with *noumea*, our mental pictures of phenomena, but he also concedes that, although human reason is an island, it is a fairly well equipped island and we can live with it.

In this sense we can live with modern science and I suggest that science alone is capable of explaining the world and science alone has a predictive power. When I receive some new information, I check if and how it fits my internal picture of the world and if it fits, I build it in, I recognise it as fact, perhaps modifying my view; if it does not, I ignore it. Similarly, any statement that is purely an assertion would be ignored. I like to listen to opinions, if well reasoned, but I liberally use Occam’s razor. I much rather accept that “I don’t know” than to accept assertions at face value as truths. My only “belief” is human reason.

### Table 2: The two sides of architectural thought

<table>
<thead>
<tr>
<th>S</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONSTITUENTS</strong></td>
<td></td>
</tr>
<tr>
<td>science</td>
<td>art</td>
</tr>
<tr>
<td>knowledge</td>
<td>skill</td>
</tr>
<tr>
<td>left-brain</td>
<td>right-brain</td>
</tr>
<tr>
<td>structured, patterned thought</td>
<td>haphazard and chancey thought</td>
</tr>
<tr>
<td>rational, often linear thinking</td>
<td>emotive, lateral thinking</td>
</tr>
<tr>
<td>logical deduction</td>
<td>analogies and icons to generate ideas</td>
</tr>
<tr>
<td>social service</td>
<td>creativity, ‘monument to myself’</td>
</tr>
<tr>
<td><strong>CONCERNS</strong></td>
<td></td>
</tr>
<tr>
<td>substance, function</td>
<td>form</td>
</tr>
<tr>
<td>space planning, flows</td>
<td>3D arrangement of masses, plane</td>
</tr>
<tr>
<td>(2D) structures and construction</td>
<td>and linear elements</td>
</tr>
<tr>
<td>thermal and acoustic performance</td>
<td>striking, innovative arrangements</td>
</tr>
<tr>
<td>lighting, esp. daylighting</td>
<td>interesting shapes that</td>
</tr>
<tr>
<td>energy economy, economy of means</td>
<td>photograph well</td>
</tr>
<tr>
<td>sustainability</td>
<td>cultural relevance</td>
</tr>
<tr>
<td>honesty</td>
<td>imagination</td>
</tr>
<tr>
<td>technology</td>
<td>poetry</td>
</tr>
<tr>
<td><strong>EPITHETS</strong></td>
<td></td>
</tr>
<tr>
<td>discursive</td>
<td>non-discursive</td>
</tr>
<tr>
<td>objective, based on facts</td>
<td>subjective, opinionated</td>
</tr>
<tr>
<td>analytical</td>
<td>holistic</td>
</tr>
<tr>
<td>verifiable</td>
<td>unspecifiable</td>
</tr>
<tr>
<td>boring, square</td>
<td>interesting</td>
</tr>
<tr>
<td>rigid, fossilised</td>
<td>wooly, nebulous</td>
</tr>
<tr>
<td>hard-headed</td>
<td>sensitive</td>
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</tbody>
</table>

So, there is a difference between scientific and artistic thinking and world-view, but the two may not be mutually exclusive. In recent years (decades) a dichotomy developed, opposing science with art in architecture. In my view there is no sharp boundary, there is an artistic element in science (both in formulating new conjectures and in assessing results, e.g. enjoying an ‘elegant’ solution) and a scientific content in all art (many artists are ‘calculating’ and produce rationally created images, such as in op-art, or are inclined to at least post-facto rationalisation of their product), especially in arts more bound by materials and technology, but even a composer would look at his/her own product (or any other composition) critically, which is a left-brain activity, using scientific thinking. It has been suggested that scientific thinking would stifle creativity (my grandpa with his set-squares?), and also that the lack of it would lead to irresponsible formalism. It may serve some purpose to compile a list of terms (both nouns and adjectives) used in the context of these two categories, which I will call just S and A, partly those that the protagonists of each would use about themselves, partly pejorative terms used by the opponents. Even a cursory examination of such a list (or some other version of it) would indicate the absurdity of relying either on ‘S’ or on ‘A’ exclusively, especially in the most utilitarian of arts that is architecture. How can we integrate the two constituents? Could we combine all the positive terms and get rid of the negative ones?

Hillier (1996) suggests that architecture is not part art, part science, but it requires the processes of scientific abstraction and the “concretion” of art. Design is a combinatorial activity, creating a configuration that is more than the sum of its parts. And combinatorial conjecture is guess, intuition. “Architects design form but hope for function.”

### 5. ARCHITECTURE

There is no doubt that architecture grew out of the craft of building. *Archai* (αρχαί) as a prefix, means chief, prime, leading, and *-tektou* (τεκτονύν), as Latinised into *-tectus*, means builder. The word has been used since the 1500s to mean master builder.

Science had an influence on architecture in the 18th century, mostly through the French engineering schools then developed, based on the rationalist thinking of Bacon and Descartes. Broadbent (1973) suggests that Descartes’ ‘rules of logic’ were derived from architecture. This was primarily the development of the science of statics and structures. The second wave of scientific influence came in the mid-19th century with César Daly and Violet le Duc (1875). The modern move in the early 20th century advocated the role of scientific knowledge. The sun was discovered as a strong influence, lighting, noise and comfort of occupants was mentioned, but knowledge of these was badly lacking. Then, in spite of the warnings of Gropius (1935), modern architecture became a “style”, the epigones imitating the forms, without the thinking that generated those forms; modern became modernism.

The more recent re-discovery of science (by architecture) comes with the 1958 Oxford conference of the RIBA. Building science (the topics suggested by the Bauhaus and CIAM) was rapidly developed in the post-war years by the various research organizations and found its way after 1958 to the schools. Unfortunately this was a short blooming. The *knowledge-base* of architecture, traditionally referred to (e.g. by Lawson, 1980) as the *science of building*, has been considered under three main headings: - building fabric — materials, construction and structures, - building environment — heat, light, sound and energy (passive systems) - building services — water, wastes and energy (HVAC and supply systems, installations).

It is this knowledge-base (also including non-technical knowledge, such as law and standards, business practices, etc) that may constitute competence in architecture, especially when referring to the
responsibility of the architect both to the client and to society.

After the Oxford conference there was much discussion on what topics and at what level should be included in the architecture syllabus. A parallel argument was devoted to the role of mathematics. There were attempts to include mathematics as a subject, to have architecture students take courses offered by the mathematics department. Others disputed the usefulness of mathematics for architects.

My argument was that some basic mathematics is essential but beyond a certain limit the student gets bogged down with mathematical techniques and its usefulness will decrease, as indicated by Fig.1. I would even concede that it is not really mathematics that I advocate, but the development of numeracy. The use of numbers to assist thinking.

Figure 1: Suggested relationship between mathematical knowledge and its usefulness in architecture

Something similar to the approach of Polya (1957). That limit (point A) would include some elementary algebra, geometry, trigonometry and perhaps some analytical geometry. This should be sufficient to facilitate the development of disciplined thinking. Differential/integral calculus would already be beyond point A, on the downward slope. A mathematical fluency could perhaps be useful (point B) but that could certainly not be accommodated in the architecture course.

More recently, architectural science came to include the above building science, with an emphasis on how such science is used in architectural design, but extended to include some areas of the social sciences, from ergonomics to architectural psychology, scratching the surface of anthropology and sociology.

The profession, very impatiently, expected science to provide complete solutions, which it could not do. A little knowledge is worse than no knowledge, it may cause impotence, as it did with my eye-operating old man. And knowledge does not make form. Many a rationalist could do very good pre-design studies or evaluate a proposed design, but is at a loss when it comes to form-making, the ‘black box’ of creativity. Thus the profession turned away from anything scientific.

Post-modernism, deconstruction and other formalistic aberrations put an end to any science-orientation in architecture by the mid-1980s. There was (and there is) however a continuous development of the building and building component technology, driven by industry and the profit-motive. Even the most formalist-minded and fanciful (right brain-dominated) architect is bound by the capability of technology. This is however (again) a two-way process. The imaginative designer may go a step beyond the limits of existing technology and force that technology to catch up with the design idea. This is true for Frank Gehry’s Bilbao museum, that could not have been done without 3D computer graphics (and CAM), as well as for Utzon’s Opera house. His original sketches (based on the sails analogy) were rationalised by himself, transformed into a series of constant radius curvature segments, which then enabled Arup to translate these forms into a buildable structure.

6. EDUCATION

In architectural education the studio is the main institution of learning. The teaching of architectural science (and of any other ‘supporting subject’) is rarely effective, in the sense that whatever is learnt, is not made use of in design, in the studio. This is the perennial subject of much heart-searching and many studies in architectural science circles.

The excellent paper given by Purcell (ANZAScA 2002) identifies ‘inert knowledge’ (or rather the inert nature of knowledge) as the barrier to integrating the lecture-input with design activity in the studio. He suggests that the cause is that lectures come from different teachers, delivered in a different place, so the knowledge gained is not connected to the design task. In terms of the above discussions, it could be attributed to the fact that structural/constructional/environmental knowledge is stored in different frames of reference, will constitute different ‘universes of discourse’. I fully agree with his diagnosis, but his remedy is only a partial solution. I concluded years ago (Szokolay, 1995) that ‘The problem is not the teaching of architectural science, the problem is the design studio’.

The studio projects have no relationship to the ‘knowledge input’. The structural and environmental frames of reference are not called up in the design studio ‘universe of discourse’. The only (at least partially) successful solution I have seen is what we introduced at the Polytechnic of Central London (now University of Westminster) in 1970-73, that I described at ANZAScA ’95. The essential feature of this was a block course arrangement. Each main ‘supporting subject’ had one group of students for one term (cca. 12 weeks), almost full time (at least 4 days per week) and was responsible for both ‘input’ and studio.

For example, in environmental science lectures were given, short exercises set, including laboratory work, but the same teachers also set the design project and conducted the design studio. In the early years these were rarely full-fledged realistic design projects, they were devised so as to make it unavoidable for the student to make immediate use of the material learnt in lectures and exercises. We coined the term controlled projects. Lectures were given in the laboratory, students initially worked at the lab. benches, in groups, argued out the design, there were group (as well as individual) tutorials in the lab. Students may have moved into the studio space for the final presentation. I didn’t encounter the term ‘inert knowledge’ at that stage, but the method certainly avoided it and succeeded in making that knowledge active.

In today’s terms I would say that the material received by the right brain was immediately and thoroughly connected to the left hemisphere and the multiple hemispherical switching created and enhanced the innervation, perhaps even creating some actual neural connections. The conceptual design problem invoked intuitive brain reactions, immediately connecting to the left, calling up the rational knowledge, linking it with the spatial functions of the right brain.

Of course we were lucky to have lecturing staff who were knowledgeable in one of the supporting subjects, capable of the lecturing input, but also full-fledged
architects, able to set, run, crit and discuss the design projects in their totality. Later, in Queensland I did not succeed in getting a similar course pattern accepted. It was argued that my ‘controlled projects’ are useless, only fully realistic projects can generate ‘architectural’ experience. We just ran the Architectural Science course for one semester of each of the first three years, but at least we had a group of students for one full day per week, that started with one or two lectures and the issued assignment had to be completed by the end of the day.

Schön (1983) contends that much of the knowledge architects use in practice is tacit knowledge (in the sense of Polya, 1957) which cannot be spelt out or written down, but it does influence our actions. We often make decisions ‘by feel’, which is really such tacit knowledge. Such knowledge is gained by experience. (The design studio is supposed to be ‘accelerated experience’, but not with controlled projects?). Very often we act ‘intuitively’, or ‘instinctively’, when that instinct is in fact such tacit knowledge, perhaps obtained by experience but never explicitly formulated.

Recently, I said to some colleagues that the best way of learning is by doing. I had in mind the above block-course arrangement. The result was that after I retired and they could not find anyone to teach the ‘supporting subject’ architectural science, it was abolished, and a studio-based ‘environmental design’ was introduced. This may create some enthusiasm for environmental issues, but very little competence.

7. CONCLUSION

There seems to be general agreement that architectural design is based on conjecture / analysis (or conjecture / test). I suggest that any design consists of a large number of C/A sequences. At the scale of the overall process of a design, the brief and pre-design analysis of the problem, recognition of the constraints, both physical and non-physical, is clearly a rational activity, using scientific tools and thinking. Optimally, this can be a definition of the ‘solution space’, or delineation of the boundaries of the designer’s freedom. Later, when a design hypothesis will have been formed, it would be considered, criticised, evaluated, analysed and tested in rational terms and developed in detail. The designer’s scientific and technical knowledge has an obvious role in both the pre-design phase and in the evaluation / development of a proposal.

I would however propose a multi-C/A theory of design, for the central, creative phase of design (to replace the ‘black box’ phase of Osborn or Broadbent). I would suggest that in this phase (which is essentially a right-brain process) knowledge also has a crucial role. This is essentially ‘tacit knowledge’ (of Schön), but could be explicit knowledge outside the ‘current focus’ (of Torey). We have a repertoire of ideas accumulated from looking at buildings, at pictures of buildings, plans, technical solutions, from reading about and study of these, but even from conversations (e.g. in crits). This is not just a repertoire of formal solutions (which may engender copying, but may just inspire new formal ideas), but also of ideas abstracted during the above ‘input’ processes, from technological information and during learning in general. They may be our own ideas, generated when looking at external inputs. When thinking of a design problem, this repertoire is scanned for relevant items. Memory can be activated by a multitude of different thought-triggers, temporal, locational, personal connotations, by analogies, pattern similarities or contrasts, even by smell. These ideas may be flashed up at the speed of light (not even consciously followed), discarded or kept, perhaps combined. This may be considered as a series of micro- C/A sequences. Even at this micro-scale the hemispherical interaction, the integrated art – science operation is essential. Ideas selected may then be consciously considered and tested, first in thought, than with the proverbial 6B pencil. It is therefore not enough to have a rational (left-brain) knowledge of science and technology. Its mirror-image should exist in the right brain to ensure a quick and painless search.

Analogy non probat, but I may be allowed to finish with an illustrative (and I hope very 21°C analogy): I have a CD full of digital photo images (my left brain). I can call up a directory, a screen-full of miniature images (right brain), from which to select the one I want. As they scroll down the screen I look at each miniature (conjecture) in a fraction of a second I follow a C/A sequence, discard or highlight that image. When I find what I think I want, I call up the full screen detailed image (from the left brain). Another C/A (perhaps ‘min’; as more than the above ‘micro’ but not yet the full, final): if I find it OK, I click, to get it printed out or transferred into my PowerPoint presentation.

The quality of the resulting architecture depends on what is included in that tacit repertoire and what are the (perhaps subconscious) criteria for selecting the idea around which the design will be built up. The role of education must be to ensure that the knowledge input is digested, it filters across into this repertoire and it is well balanced, consists of not just formal ideas, but ideas abstracted from studies of structures, building technologies, climate-responsive thermal behaviour of buildings, sustainability and from general reading. In fact from the totality of the educational and socio-cultural experience.

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