On design reasoning: lessons from teaching architectural technology

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Reflection on recent courses in architectural technology give indications of a useful pedagogy linking design reasoning and building construction thinking. Building on the concept of thematic systems in architectural design, students were asked to generate variants on basic assembly situations in particular buildings. This was the basis for beginning to understand a systematic way of evaluating alternatives, as well as a way to take measure of the extent to which design intentions and considerations of architectural technology could be uncoupled.

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> I make a *design* when I don't know what to draw . . . I make a *picture* when I know what to draw. (Yumi, a 6 year old child explaining her drawings)

Two recent experiences in teaching an introductory Architectural Technology course have provided lessons on certain aspects of design reasoning in connection with architectural technology. By design reasoning we mean the explicit thinking and doing that goes on in devising a plan, on the basis of which some artefact can be made by someone else. By architectural technology we mean the people, physical parts, techniques and processes which together make buildings.

The courses referred to were introduced to students—undergraduate pre-professional environmental design students—as experiences to help them understand how to link considerations of technology and construction to design intentions.

When a design is in mind, the students are told, it is a good idea to begin to formulate ideas about the materials, systems and processes available to realize those images—those material systems and actors who must coordinate themselves and the subsystems they control to realize a design. But while this is heavily stressed, the other direction of thinking is also pointed out:

- Materials, systems and processes also inform designing.
- Images of a design may emerge from knowledge of building systems, their interactions and construction processes.

So, the lectures and the labs—both field trips and small design exercises—always stress the reciprocal means/ends relations, of building parts and technical processes, and designing.

Having said that to the students, some confusion is inevitable when they are told that the course also aims to *uncouple* design intentions from specific construction strategies. The proposition is made that for any design image at any 'level' of detail (whole building, infill systems, or building nodes), there are >1 alternative materials systems to be considered, and >1 alternative construction strategies to be considered—including parts and processes—at each of several 'stages' of designing work. These stages refer to the normal, though often unsystematic, steps of moving from image to representation, a staged process of many iterations, each more detailed and specific than the preceding one.

The purpose in saying this is to help students reject the notion of a one-to-one correspondence between image and materialization. This may have seemed impossible to the students, and contrary to good practice, but we asserted that it is not. Students often found this hard to accept when they were already comfortable with the cult of self-expression and 'integrated' thinking so often found in school. It seems that the simplification enabled by the idea of a one-to-one correspondence between image and materialization is a conceptual strategy aimed at a control of complexity. This may be acceptable and convincing when there is only one party deciding in a complex project; but when there is more than one decision agent involved, it is very useful to understand how to uncouple the image from the materialization, in order that a shared image can remain a constant agreement, while alternative technologies and strategies can be explored to realize it.

On the one hand, the course stresses help in understanding how to realize design intentions, whatever they may be. On the other hand, the course stresses the concept that design reasoning—when construction is in mind—can be understood as a nested set of design images. The students see a diagram like that shown in Figure 1. They see that the concept of variations on a theme is the main idea; that for one principle, or theme, there are variants at the next stage that may be considered for realizing that theme in detail, and so on in the chain of representations leading to making the artefact.

This means generating variants or alternatives. We need to ask 'What different ways can I build what I have in mind?' 'What are the principles of form, position and

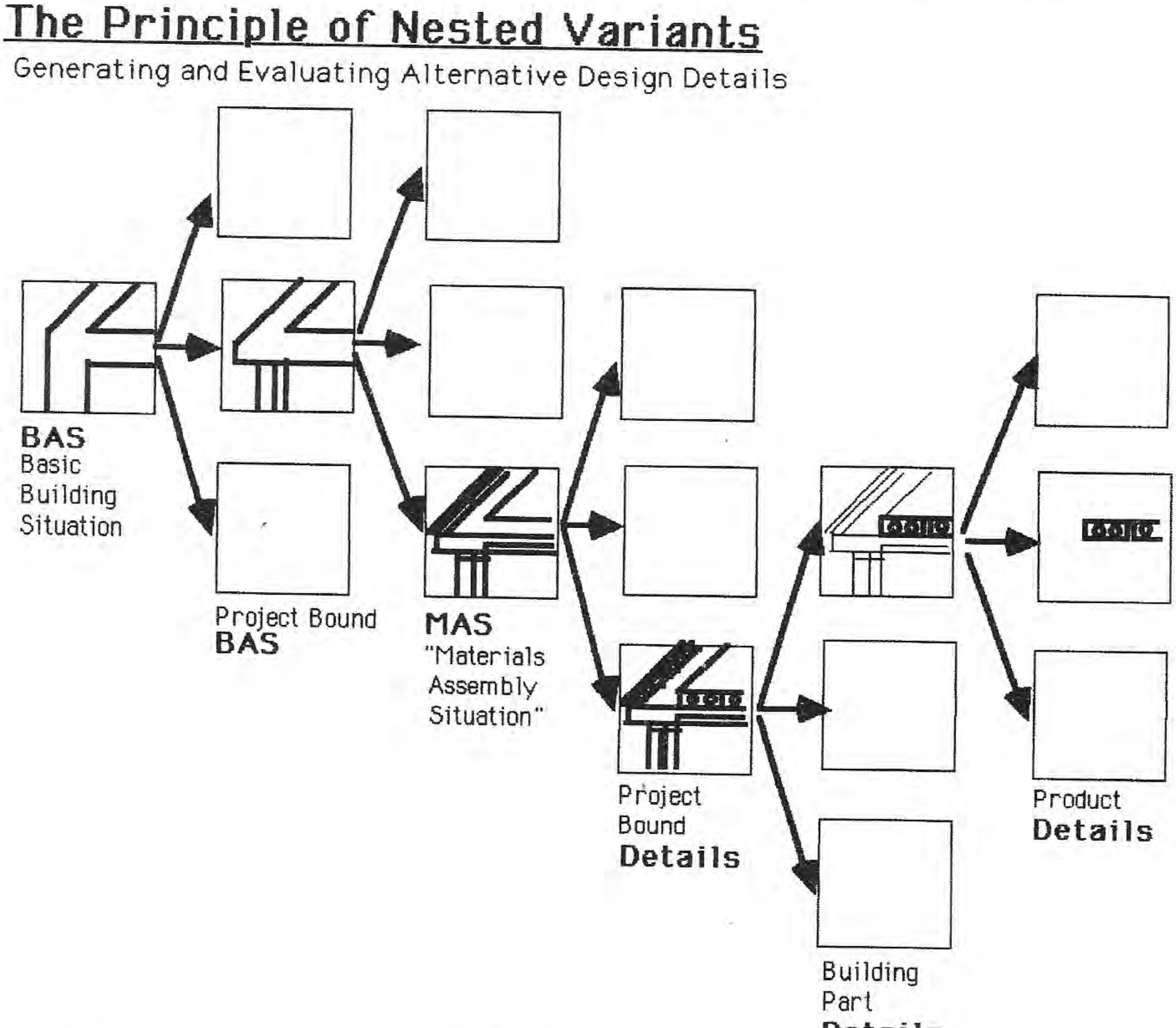

Figure 1 Principle of Nested Variants (adapted from van Randen, 'Plans and Details according to NEN 2883', May 1981). Generating and evaluating alternative design details

dimension of elements, the assembly sequences and appearance attributes?' 'How bound up is the image I have in a particular building technology?' 'What are acceptable 'margins' of variation or indeterminancy the image will support?'

Secondly, it means evaluating the variants that are generated. 'What criteria should be used?' What are the performance requirements of the parts, their arrangements and interactions?' 'What are the costs?' 'The implications on logistics?'

Fully exploring and addressing these two questions—of generating variants or alternatives on some reasonable basis, and of evaluating the variants so that a proposal can be formulated—means examining and knowing design intentions explicitly, if for no other reason than realizing that designing is a social process involving communication and coordination among many agents and elements.

This kind of thinking means exploring construction concepts, and by so doing often finding fault with the original design image that started the search in the first place. Having begun to understand that there is a systematic way to doing this, students find that they can back-track—that is, they can find their way back to some theme or set of principles that remains sound—and then go down another path toward a fully described design, in the same propose–evaluate chain, as shown in Figure 2.

Exploring options in terms of elements, processes and their relations for the same image is then a very practical thing to learn to do. The course aims to give help in getting started with that job.

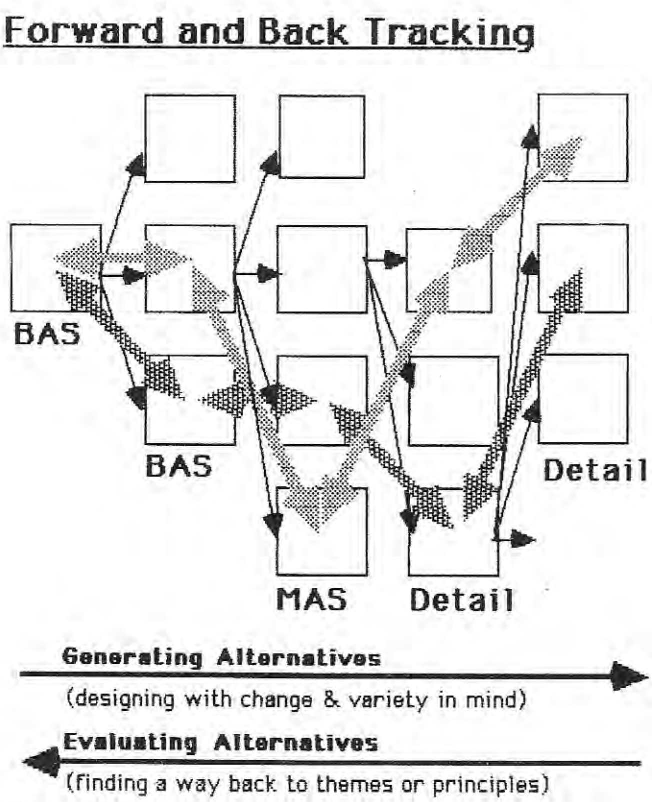

Figure 2 Forward and back tracking

- This work also turns out to be intellectually challenging.
- The job is complex, since there are so many parts, so many agents, so much change to come to grips with. Also, there are the shifting ideas and images of what the design can be, coming from the designer's personal impulses and insights, the clients demands, the contractor's practices and estimates, the site itself and other forces and agents.

WHY ARE THESE ISSUES OF INTEREST?

There are two principle concerns here. On the one hand, there are concerns of the intellectual life of architectural education. On the other hand, there is the work of preparing young people for the requisite professional competence of practice in cultivating the built environment.

An issue of intellectual life

In working from these starting points, we have found it necessary to deal repeatedly with an important issue in design education. This issue—of the intellectual life of architectural education—has to do, in part, with a false conflict that is posed between imitation and creativity. There seems to be more confusion than clarity on this subject.

It is sufficient here to suggest that somehow, the notion is alive and well in some places that imitation is to be avoided and creativity cultivated above all else. 'Imitation is bad, creativity is good', it is claimed. We see courses on stimulating creativity, glorifying it and the cult of uniqueness and expression. We see rules, inconsistently applied, against imitation.

What false premises for a role in architecture! What is this but a sure way to produce schizophrenic, intellectually impoverished and confused practitioners? What can this do but make cynics and produce doublespeak?

Let us say that creativity is a difficult word and concept in any case. We hesitate to use it, thinking that we will be understood to be involved in metaphysics. We think of Koestler's work[1], for example, as representing a certain clarity of thinking on the subject, but knowing that there is a whole literature on this, and entire academic careers dedicated to thinking about it, we shy away from saying much at all. Creativity is, after all, not something claimed only by architects!

In the field of the history of technology, for example, the concepts of creativity, invention and innovation have been the subject of debate since the early days of the Society for the History of Technology[2]. So it is in the field of psychology, science and all other fields.

There is great importance, in this debate, in recognizing that there is a significant distinction to be made between the concepts of creativity and concepts of designing[3]. It is this distinction which merits further recognition in the field we address here.

- Imitation seems closer to the mark of what designing—and building—are all about, than creativity, if one must choose. But why should we want to choose?
- Imitation is not to be scoffed at. It is, in fact, the basis for much of the best in childhood learning. One could say that the business of early childhood development is creative imitation, in cognitive development, muscular development, and the development of values and the will![4]

The operative word which comes closer to the work of designing is *transforming*. We take forms that we know, and redo them. We take a site and propose that the ground be shaped. Someone else operates the grading equipment to do the shaping. We do not create. We see steel sections and propose configurations made up of shapes we can buy ready made, or we can propose to reconfigure shapes, or order new shapes from steel alloys. We use glass in both the same ways and in different ways from what we have seen, but we do not create glass. We propose spaces, bounded by physical elements we imagine, and find the spaces 'like' others we are familiar with, but unlike them in particular ways. We design buildings like buildings we know, but in some ways different.

Imitation, we have found, is to some students a kind of cheating. The important thing, many feel, is to make 'unique' things. When we tell them that they can feel comfortable in employing bricks, or stairs or kitchens in their proposals, even if they are not the first such elements in the world, they seem confused. 'Yes, but that's not what I mean; we want to be creative', they say. The issue of convention then comes up—how we usually begin with a conventional form, begin to tweak it, shift it, make little incremental adjustments of it, then on and on to a final proposal which we understand precisely in relation to the conventions in which it lives.

We have found that when students can understand this, they can see that óne need not feel lost, that imitation is not a plunge to loose oneself to the form imitated, that moves of transforming a conventional pattern can be undone. Then, new doors of the mind open for the students. It is quite exhilarating to see.

The connection to architectural technology is direct and clear. We begin with what we know—the boards, the tiles, the pipes, wires, cement, steel beams, the windows, walls and floors. We do not invent these objects, but build with them.

But we begin also with images, or wholes, that are more general than the particular elements by which they might be realized. Every building of a type, we say, has an eave, a foundation, a wall/floor intersection, openings in walls, resource distribution systems penetrating interior floors, and many more such 'wholes'. We do not invent these, create them or find them unique in the world. They are the shared repertoire of building forms and systems, which in one way or another let us identify forms and building systems as belonging to families. We just have to observe carefully the extent to which these conventions prevail, even while their realizations differ from building to building and place to place.

An issue of professional competence

The second issue that matters for questions of pedagogy is that of rapidly increasing pressures on architects to manage more and more complexity, larger projects, more regulations and more variety. This is a difficult mix indeed.

Complexity

The issue of professional competence has to do, in a major way, with an ability to control complexity[5]. The complexity we face is in large measure a result of change, of variety, and of interaction among materials, people who decide, regulations and techniques. These forces present formidable hurdles to any design reasoning. Clients change their minds and programmes; contractors suggest alternative materials or techniques; engineers propose different systems; we even change our minds during a design process, regardless of what others may think or do. And buildings keep on changing: they are altered, renovated, added to, moved. It is a complex game.

Examples from practice have been useful to make this point. For example, a story is recounted of a large regional high school on which the author was project designer, in the western slopes of Colorado. The initial concepts had been to use themal mass for energy conservation purposes, suggesting precast concrete double Ts for the large sloping roofs and the floor system. This took a distinct architectural expression. Building planning and massing proceeded with this image and technology. At a certain point, the construction manager of the project reexamined the construction critical path, and decided that he could not support the use of precast concrete, given severe weather conditions during erection of the frame and labour and material problems in that remote area. He insisted on changing to a steel frame. We had no time or budget to redesign the plan and building massing, but had to adjust many things to the change in structural system, including the entire detailing concept for the building and the concept of thermal mass.

Other examples in hospital design, office building design and residential construction make this point of change *during design*, on the initiative of other agents: owner, contractor, suppliers—very real.

Learning to be competent when we do not control the game, the change, the variety or the interactions, but play by rules we find already in place . . . that is what we do most of the time in practice. On the other hand, we may find ourselves in a position to frame the rules in a new way. But in such a case, we have to convince the other agents to play by the new rules, a difficult thing to do, which often means we go back to playing by existing rules simply because it is easier, and we have chosen to confront other issues.

Risk

How risk is undertaken and managed is another measure of competence. We may take risks when we know how to get back to secure ground. Perhaps this is measured risk-taking. We find that students today are, by and large, very risk aversive. They don't try very daring things, or even slightly risky things. We do not mean making silly or capricious decisions, since we understand risk-taking as what we do when we realize consequences but go ahead anyway. Perhaps it is because they are on unfamiliar ground, or feel their skills are too immature. Perhaps it is a way of working that they lack, a way which might put some solid ground under the impulse to strike out in an untried way. Taking risks may be limited by the lack of adequate tools by which to keep track of the way back to the home base.

This risk-aversive behaviour points to the need for conceptual tools for teaching and continued learning.

VARIATIONS ON A THEME BY . . .

With the idea of the nested variants or Building Node (Figure 3) in mind (all lectures dealing with basic material systems, systems interactions, construction logistics, code issues, and so on are organized on this basis) we focused on the work of conceptually uncoupling designing and technology through the discipline of identifying thematic principles. This was done in two ways.

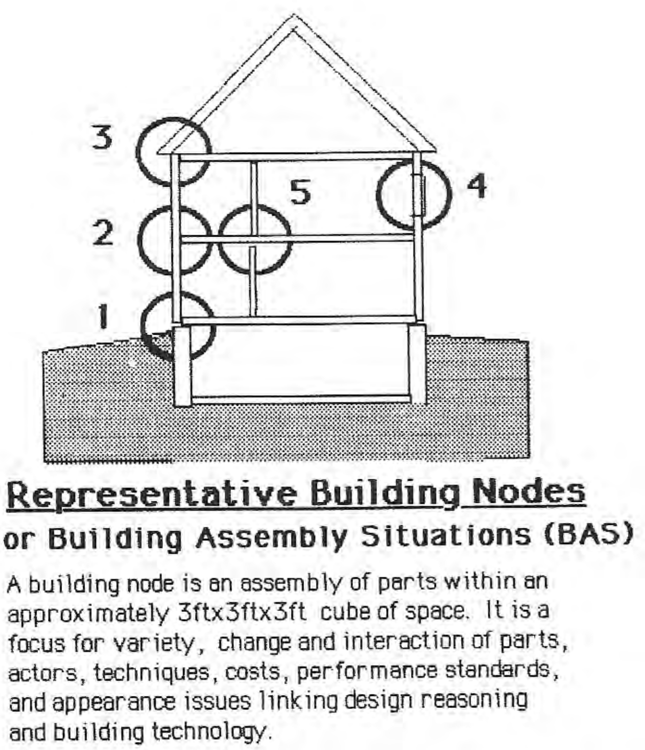

Figure 3 Representative building nodes diagram or building assembly situations (BAS) (from: Van Randen, TH, Delft, the Netherlands)

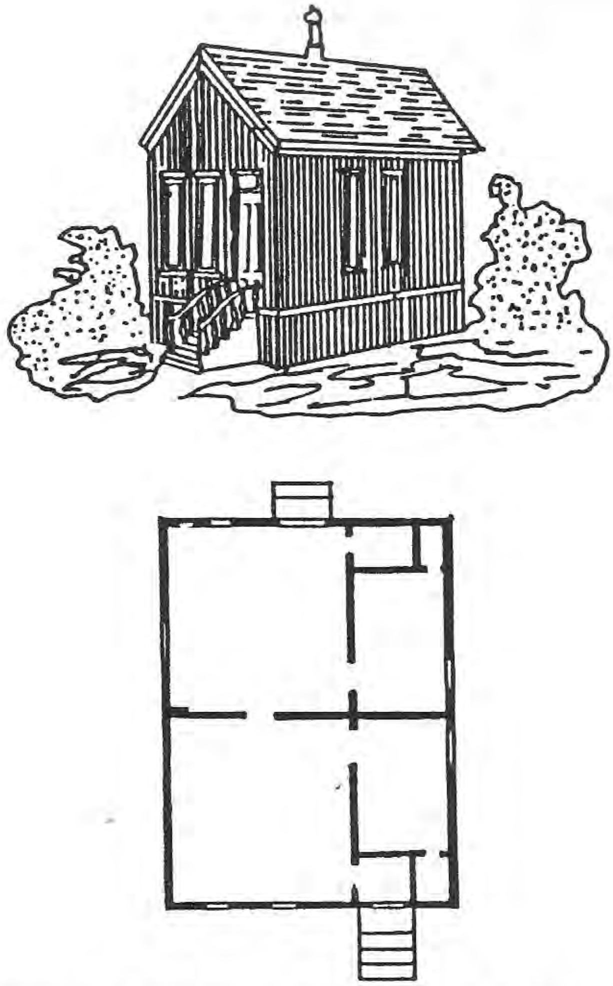

Figure 4 Colonel Bridges' house, in a book on 'vernacular technology'

Colonel Bridges' cottage

First, we used Colonel Bridges' portable cottage (Figure 4), found in a book on 'vernacular technology'. In a series of four sketch exercises in the workshop piece of the course associated with the lectures, we explored this simple building in four material systems: wood, masonry, steel and concrete. Preceeding each of the in-the-workshop exercises, students visited a construction site in which the material in question for the next workshop was in use in a major way.

In small teams of three, students sketched variants on the image before them—Colonel Bridges' cottage—in the material system of the day. There was no single way to do it. The idea was to explore variants.

The wood exercise was easy. The cottage was already in wood, so there was no apparent tension in the exercise. Students just had to sort out framing, eave details, stairs and so on. The problem of interpretation, or maintenance of thematic systems, was relatively quiet.

Nevertheless, we found some students having to rein in their grand schemes by the restraint of their team members, whose impulse was to keep close to a strict interpretation of the cottage. In most cases, the rather obvious discrepency between plan proportions and the pictorial representation (distorted as it is perhaps for marketing a small house to make it appear grand?) caused confusion that needed to be settled by agreement.

The next exercise was in masonry, preceded by a visit to a brick manufacturing plant. This time in the workshop, the issues of thematic systems began to become evident. Students in the teams disagreed with each other on what constituted a thematic principle in the cottage. These disagreements were not abstract, but came directly from the need to 'make' the cottage in masonry. Sketches appeared, were discussed, changed, and soon agreements came about. In the 2 hour workshop, by the pressure of time, students agreed on new renditions of the little cottage.

The next exercise was in steel. 'A steel cottage?', students asked; 'That feels so out of character'. But that was the assignment—to render the thematic systems in steel, and to come to agreement about what elements of steel would be positioned in which relations with other elements. Some students rigidly maintained proportions of windows, the vertical siding; the pitched roof. Others boldly suggested schemes maintaining the plan form, but making a flat roof. Teams struggled over the competing concepts which each proposal illuminated.

The last exercise was in concrete. Precast concrete was prescribed, to get students to come to grips with repetitive large elements, joints, and the question again of thematic systems. Students asked themselves 'Is it in the details that the cottage has its main identifying traits?' 'Is it in the plan organization, or roof slope?' 'Maybe it is in the vertical exageration of the tall windows and vertical siding'; 'Can we change the roof form and still keep certain thematic principles?' Sketches showed such queries.

The objective in this was certainly not to suggest that any building, or any detail, can be made of any material. The object of the exercises was rather to bring some dissonance into what is too often a convenient collapse into obvious solutions, on the one hand, or a vigorous abandonment of convention on the other. It also had to do with bringing some alternatives into agreement making: to make students articulate in words, but more importantly *in sketches*, what they considered to be in keeping with the thematic systems they personally observed in Colonel Bridges' cottage.

The perverse idea was that by pushing on the image, through trying to realize it in alternative material systems, students could get closer to *an understanding, albeit largely intuitive or implicit at the time, of what thematic systems are when architectural technology is in mind.* But it was not good enough that each student privately come to an understanding of what was essential to the cottage—the group must reach agreement. And the best way to agreement was to represent ideas on paper, to engage in designing as a means of agreeing.

This is somewhat akin to the idea that a person will really come to understand a concept if it can be understood in at least three languages. Two languages appear not enough, but three gives concepts three coordinates and lets the concept begin to exist in its own right above any particular language, to transcend language anchored concepts. A similar idea is the subject of research at MIT in the School of Architecture and Planning's Design Research Seminar, led by Professor Donald Schön, in which the question of multiple representations of a same design concept is being explored by designers, philosophers, musicians, psychologists, and computer scientists[6].

Similar concepts can be found in the study of language and concept formation, in the work of Vygotsky[7], Quine in his study of language and translation[8], and in Bartlett in his thinking about what he calls cognitive schema[9].

This parallel in the development of mind is fascinating since we could see students really coming to grips with the thematic systems of the little cottage only after much exploration of variants—in this case, variants in terms of architectural technology. It is like the idea of really understanding what a *chair* is after seeing several kinds of chairs and then, and only then, understanding the concept or the thematic system shared by all the variants observed.

The sketches of the workshop sketch exercises were predictably sloppy, amateur, often technically inept. But these were not unanticipated in a first course in building technology.

Two houses

Over two semesters in the same course, we ran a parallel 'semester' project, using the same teams of students as in the workshop exercises, to produce a study of two houses in Boulder in four material systems—the same four material systems explored in the workshops.

These were houses the students could, and did, visit. Fully documented, the houses presented themselves as real, experienced artefacts. One was a single family house in a residential development, with a steep gable roof, and sided with natural cedar siding. The other house was a more special house, with white horizontal siding, exposed wooden trusses, and a very special arrangement with a semidetached bedroom/study wing.

On the basis of a tightly formated 24" × 36" presentation sheet, student teams were required to produce a set of drawings of these houses reinterpreted with particular material systems in mind.

Again, the same issues came up. What could the team agree was essential about these houses? What constituted irreducible thematic qualities or characteristics? How could these be maintained in a different material system? What intrinsic characteristics of a required material system simply had to be respected, forcing an adjustment in the 'picture' of the existing house?

These questions again found their place in the interaction of the small teams doing the work.

Some students wanted, again, to make 'big move' changes to the houses, wanted to change floor plans, rearrange massing, alter window patterns. They asked, 'Is it OK to make the pitched roof flat when we go to a concrete panel facade?' The answer always was 'You must reach agreement among yourselves about what constitutes a thematic principle; don't expect an answer from me.' Some found that making the big moves simplified the application of a different material system. Some teams found that they were content making the small detail moves without questioning the 'big' issues of building form and plan.

Team dynamics was also an issue in some cases. Students come with different competencies in thinking through the technical issues of making what are essentially design development drawings—accurately drawn, noted and dimensioned; the differences in skill level had to be worked out in each team. Students also come to teamwork with different group work skills, commitments to the project and the course, and professional expectations, and these had to be resolved as well within each group.

REFLECTING ON THIS WAY OF TEACHING

To reiterate, the object of these projects and exercises was *not* to assert that any building image could be made in any material system.

The *object was to probe the extent to which design intentions, and considerations of architectural technology, could be uncoupled. We have only begun to search this question.*

To this extent, the projects, accompanied by the work on the BAS concept,[10] taught the students a way of thinking that could be a tool in their future learning for understanding design reasoning with construction in mind.

To be sure, we find whole families of building types in which we recognize individual instances made in quite diverse material systems, but which nevertheless we can still agree belong to the same family. But there are margins of uncertainty when we begin to question which family an instance belongs to. Does the questioning have to do with massing, materials, relations of openings to solid walls, details, all of these, some of these, other things? What really constitutes a thematic system?

These are interesting questions for educators in the field of design and technology, for those teachers who would like to understand the 'cognitive schema' by which the complexity, the change, and the variation can become familiar and accessible to students. Coming to a perception of principles; understanding how groups come to see commonalities in a building on the basis of which individually arrived-at variants can be agreed to be in sympathy; understanding transformations of an image and understanding what is shared across a number of transformations of that image. These are some of the challenging questions that have been raised by this teaching.

Thinking about the relation of design and technology in this way has led us into a new dimension of teaching and inquiry, in an area of the field of architecture that is often relegated to obscurity and rather boring and lifeless 'how-to' texts.

These are also—and most important we think—practical concepts for architects to learn in relation to architectural technology in daily use. We have tried to raise them in challenging ways—in a course dedicated to site and material systems—that would carry over to support continuing curiosity and learning about the relation of design reasoning and architectural technology.

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