0081

Architectural Thought Experiments, Verisimilitude and argumentation in predicting architectural quality

J.L. Heintz
Delft University of Technology, DElft, Netherlands | heintz@bk.tudelft.nl

Introduction

One of the most common models[1] of design consists of three steps – analysis, synthesis and evaluation – bound together in a cyclical pattern (Lawson, 1980). This corresponds well with our notions of design at many levels: That of a single designer working at his or her computer, analyzing some small element of the brief, composing an architectural solution or perhaps a variation on an existing design, and determining that the design intervention will meet the requirement of the brief; that of an office in which staff are given a brief or a section, on the basis of which, they create a design, and this design is reviewed by senior staff; and that of a project team in which the client and project manager prepare a brief, the architect designs to the brief, and the client and project manager determine if the design meets the brief.

An interesting thing about architectural design is the degree of prediction it requires. Where as in product and engineering design, in graphic and interface design, it is possible to construct demos and prototypes and have potential users interact with these – giving their opinions and reactions to the design. In architecture, it is not possible to test how users will interact with the building before construction. Yes, there are models, fly-through, drawings, and no end of architects describing what will happen in their buildings once they are built, but this just does not have the same level of confidence as testing prototypes. Architects, project managers, clients and users must all predict how they will receive the planned building and how well it will meet their needs. They must all predict the future.

Yet predicting the future is a dangerous occupation. Architects are used to using their intuition to create spaces which they anticipate will suit their future users. However, it has been noted that architects often design for

[1] Lawson uses the word 'map'.

‘users’ that are little more than mental homunculi behaving more or less as the architect would wish them to (Ellis & Cuff, 1989). This often leads architects to engage in what I call wishful thinking, expecting users to obey the architects desires about how people will receive, interpret and interact with his or her design. Further, it means that architects may often neglect relevant user characteristics that will shape how people will interact with the building.

As an example of this is the design of a crematorium in the Netherlands which there is no heating in the ceremonial hall. The hall is of wood and glass, reminiscent of an unclad timber frame. Heating pipes and radiators would spoil the purity of the effect. The architect argued with himself claiming that because ceremonies rarely last more than 20 minutes it would not be necessary to heat the hall. He failed to acknowledge that the public would normally be elderly and that elderly people are often very sensitive to the cold, especially when sitting still.

In a second example, an architect wanted an elevated office block to be transparent – he wanted the viewer to be able to see the interior of the glazed block from the street.. He therefore used a non-reflective glass. As a result, when the office staff moved in, they brought their umbrellas with them – to shade their computer screens so that they could see their work.

These may be unusually egregious examples, but it seems reasonable to claim that We still need a means for evaluating designs rather than finished buildings, in particular a method which can be used both by architects at their desks and by clients, either singly or together. I would like to make a modest proposal, a method for testing the quality of design schemes – the degree to which the designed building will actually meet the goals of the client and designer.

Need for tools

In an ideal world, we could design prototypes, and observe how users interact with, in, and occupy, the spaces we design. This is, after all, what product designers can do – test their products. Architects, and developers, simply do not get a chance to do this. There is no budget for prototyping, and there is no chance for post-occupancy evaluation. Design budgets are also much smaller that the costs of making a building, whereas in most design disciplines design costs are many times the cost of a single example of the design object. Thus every building is a form of speculation, a form of prediction. The designers believe that this building will serve its users well, but they do not know – they can not know. They do not have the tools to enable them to do this.

Maybe, maybe not. We do have a great deal of knowledge of how people behave in buildings and in response to the way buildings are designed. This knowledge is partially available as research results in environmental psychology and related disciplines, partly in the criticism of buildings by architects, architectural critics and outsiders such as Stewart Brand (Brand, 1997) . The principal source of this knowledge, however, is the wealth of experience and observation available to us all as ordinary people who have spent the greater part of their lives in and around buildings. The question is how can we deploy this knowledge to make reliable predictions of the results of a design decision?

To answer this question, I propose here a tool combining thought experiments, and Ensembles of Use as proposed by Richard Hill. The proposed tool, the architectural thought experiment, will, I hope, have the advantage of speed, and can (at least partly) fulfill the role played by physical testing.

In proposing the use of architectural thought experiments there is some danger that readers may feel that I am merely bring out an old hat – an idea already well known and understood in all its limitations – used or neglected as individual architects and educators see fit. Some will say that design methodology has been largely abandoned as failing to address, or even be meaningful to, designers. Others will point out that architects already do much of what I am proposing (I will come back to this later). I hope that you will suspend that natural skepticism, as I am going to try to show that if properly stiffened with suitable tools and brushed off again, this old hat can still keep the rain out of our eyes.

Thought experiments

The notion of the thought experiment has a long history in science. Simply put, a thought experiment is an experiment that we perform in our imagination rather than in a laboratory. It may be facilitated by drawings of other representations, but these serve only to specify and communicate the conditions of the experiment. Well known thought experiments include Schrödinger's Cat, and Einstein's meditations about trains traveling at the speed of light. Like a physical experiments, a thought experiment is a test of a belief about the world, a physical theory or law. Thought experiments do this by exposing contradictions in, and deriving unexpected results from, existing theories, and even by creating new knowledge of the physical world (Kuhn, 1977). The great nineteenth century Viennese physicist Ernst Mach[2] wrote on of the classic accounts of through experiments.

"Besides physical experiments there are others that are extensively used at a higher intellectual level, namely thought experiments. The planner, the builder of castles in the air, the novelist, the author of social and technological utopias is experimenting with thoughts; so, too, is the hardheaded merchant, the serious inventor and the enquirer. All of them imagine conditions, and connect with them their expectations and surmise of certain consequences: they gain a thought experience. However, while the former combine in phantasy certain conditions that never occur together in reality, or imagine these conditions accompanied by consequences that are not connected with them, the latter, whose ideas are good representations of the facts, will keep fairly close to realty in their thinking. Indeed, it is the more or less non-arbitrary representation of facts in our ideas that makes thought experiments possible." (Mach, 1976)

[2] System International units of measurement are often given the names of great scientists. Mach's name is thus familiar to most people as the unit of speed equal to the speed of sound.

For Mach, thought experiments are a formalization of the kind of thinking used by all of us when we try something out in our imagination. Working on a puzzle, for example, requires us to form a hypothesis about how the next piece will fit, and then to try it out – see if it fits. Once we have gained a little familiarity with a puzzle, we can try out the fit mentally, without having to actually move the piece into position.

Mach relates thought experiments to the practical thinking of people who are interested in the world and its changes. Mach explicitly connects thought experiments with design and innovation. He wrote:
"[George] Stephenson may be familiar, from experience, with carriages, rails and steam engineers, but it is by first combining them in thought that he can next proceed to build a locomotive in practice." (Mach, 1976)
By varying the properties of the carriages, rails and engines Stephenson was able to develop a working design. He was able to anticipate the relative performance of different configurations, and to reduce the amount of testing he had to do to a reasonable level.

Thomas Kuhn states that thought experiments rely on a certain degree of *verisimilitude* for their validity (Kuhn, 1977). He goes on to say: "Nothing about the imagined situation may be entirely unfamiliar or strange. Therefore, if the experiment depends, as it must, upon prior experience of nature, that experience must have been generally familiar before the experiment was undertaken." (Kuhn, 1977) By picturing familiar things in specific, sometimes unfamiliar, settings, scientists can discover both contradictions within existing theories (as Schrödinger did) or even discover new facts about the world (as Einstein did). Their degree of success is often determined by their ability to describe the experiment conditions sufficiently well, and set out their argument in sufficiently explicit logical steps, that their scientific community finds the experiment irrefutable. These two requirements – verisimilitude and logical argument – will play an important role in our development of the architectural thought experiment.

Thought experiment in architecture

Thought experiments can be used in architecture where ever an advantage can be gained by structuring the activity of designers: to test ideas on the drawing board (either singly or in groups), and in conversation with clients to help them better understand each other, to understand the anticipated use of the facility, and the design scheme(s) proposed by the architect. Though experiments can also be used in education and staff development. In each case, the utility of the scenario lies in allowing both designers and clients to have some of the advantages of prototyping before construction starts.

We must also distinguish between architectural thought experiments and the unstructured imaginings that are part of every architect's design activities. For speculation about a design to qualify as an experiment there must be some sort of test of an experimental hypothesis. The design must be evaluated against some sort of preexisting expectation. An expectation that the building, as designed or as built, will perform in a specific way. Thus a thought experiment in architecture should consist of a conjecture or hypothesis about the performance of a design and a test of that design. In performing our architectural experiment we will imagine people, users, occupying the designed space and going about their daily activities. How to do this in a way that may have somewhat more validity than the imaginings complained about by Ellis and Cuff is the subject of the rest of this paper.

The application of thought experiments in architecture faces at least four obstacles: 1) the normal level of description of the function in architectural programs, briefs, and general discourse is high (vague) and does not normally specify the activities to be undertaken in the future spaces, 2) the description of architecture form is of such a level of abstraction (in comparison to appearance models and prototypes in product design and software development) that it is extremely difficult to meaningfully test such representations, 3) buildings are large modular structures with distinct functions and activities distributed among their parts (unlike most products, people are the process in architecture, and thus the user lives "under-the-hood", and 4) the influence of wishful thinking. Taken together these factors have significantly hindered the application of scenario thinking in architectural design. To deal with these problems a I will review a number of concepts already available to architects and propose an experimental protocol or procedure. But before doing this, we should attend to the source of the verisimilitude that will lend validity to our experiments.

Tacit knowledge

We all learn from our interaction with our environment. It is happening all the time. Of course there are many lessons we learn as children that seem both obvious and trivial to us – that glowing things are generally hot, for example. But we learn a great deal that is non-trivial which we use daily in going about our lives, but which remains tacit. We don't even know that we know it. Mach wrote:

"Unintentionally and instinctively gained raw experience gives us fairly undetermined pictures of the world. It tells us, for example, that heavy bodies do not rise of themselves, that equally hot bodies in each other's presence remain equally hot and so on. This seems meager, but is all the more secure and broadly based. Planned quantitative experiment yields any details, but our quantitative ideas educated by experiment gain their surest support if we relate them to those raw experiences." (Mach, 1976)

This is especially true of our knowledge of the built environment. We study architecture formally in classes, by reading, by analyzing plans, by visiting great buildings, and by reviewing post occupancy evaluations. But we also know a great deal about architecture from what we learn going about out lives, which, of course, take place within buildings. We, architects, are also users. We know how to use buildings, both in a general sense (how to occupy a house) and in a specific sense in which we know how to operate the surfaces, openings and controls (window cranks, door handles, etc) in buildings. We know how to sit on a window sill, or turn ourselves to enjoy the sun shining through a window.

This knowledge, however, is not explicit. It is not available to use as a series of propositions or rules about the design and use of buildings. There is certainly a body of explicit knowledge about the design of buildings, but greater store of knowledge that we have about using buildings is tacit.[3] It is bound up in our habits of working and living in and around buildings. It comes immediately to the surface when we recognize conditions that will delight of hinder us in our physical surroundings, but as often as not it remains below the surface. Hidden in just the way Heidegger claimed that the properties of a hammer are hidden from our attention when it fits our hand and task well (Winograd & Flores, 1986). Plans models and other architectural representations alone are likely to be too abstract to trigger tacit knowledge. Architectural thought experiments are intended to elicit tacit knowledge by referring to specific and familiar actions and to specific persons wherever possible. We will return to this in the description of the experimental procedure.

Three Key Concepts

Before describing the architectural thought experiment itself, we need three instruments, concepts that will assist us in achieving the verisimilitude and argumentative rigor. Two of these are concepts, *form-operation-performance*, and *ensemble of use* were developed by other researchers, but have not achieved wide recognition. The third, *users*, is ubiquitous but will require revisiting before we can perform our experiment.

Form operation performance

Function and *use* is have proved to he notoriously difficult concepts for designers or design researchers to define or make use of. We think we know what we mean by the word use, but in fact we use the word in a variety of different ways. There is the officially designated use. One might call this the teleological use – the reason for the thing. The use of an office is to do office work. However, this is so vague that anyone not already familiar with office work would be left no better off. We could then break down this "use" into a series of component activities. The difficulty here is that these activities taken in and of themselves are very often pointless. There is very little value inherent in the act of stapling sheets of paper together, yet this is (still) an activity that is performed in the context of "doing office work". *Function* presents the same problem. If we cannot agree on how to properly characterize the function or use of a building, then we will have little success in relating this to the form of the building and making a useful evaluation.

In electrical engineering there is a problem in characterizing the relationship between the physical design of a circuit and its ability to perform the function for which it is being designed not unlike the problem we have in architecture. None of us care about the current or voltage at any given point in a circuit within an appliance, a radio for example. What we want is to be able to listen to and enjoy a radio program. The relationship between a certain constellation of resistors, capacitors, and transistors and our enjoyment of a radio program is no clearer than the relationship between the nature of a floor covering and the success of school program. And yet there is a relationship. Electrical engineers speak of three things when they wish to describe an appliance

[3] For an explication of tacit knowledge see (Polanyi, 1967)

such as a radio: its structure (the physical arrangement of components and their connections on a circuit board), its behavior (the current and voltage values at each point within the circuit), and its performance (the amplification and distortion levels of a signal passed through the circuit, which in turn are the physical characteristics of the sound we get out of the radio).

Borrowing this trilogy from electrical engineering Alexander Tzonis proposed a similar set of terms to apply to buildings: ***form***, ***operation*** and ***performance*** (Tzonis, 1992). He proposes that by providing two levels of description of the buildings function, we can make the relationship between built form and use clearer and more accessible to evaluation. We will review his definition of each of these terms, but shall alter the order in hopes that that will make the definition of the most difficult term *operation* easier.

Form

The form of a building is simply its shape, its materials, and the ways in which these materials are combined or fastened to each other. When we excavate an archeological site, we discover the form of a building. The form of a building can be observed directly, or as it is described by design documentation, such as drawings, models and specifications.

Performance

Performance corresponds to the degree to which the building fulfils its reason for being. A school building should shelter and make possible the activities that constitute a school. An office building must contribute to the productivity of the workers within it. The term has come into use in project management, particularly as *performance specification*. This use s very similar, but here we wish to focus on a level description of performance that relates directly to the mission of the institution to be housed. It is therefore a description of the atmosphere, the flows, the conditions both physical and social which the client wishes to see created in the future building. Performance cannot therefore be expressed solely in terms of the building itself. It is performance of the person, practice, form system that concerns us.

Operation

Between form and performance are the lower level actions that bring us into direct contact with buildings, and which depend on the environmental conditions created by the building. These actions are in themselves not directly related to the goal of the client institution, however, they are the means by which the people participating in that institution carry out their role in realizing that goal. An accountant sits at a desk, works at a computer workstation, will occasionally make a telephone call or confer with a colleague. It is not essential that bookkeeping be done this way, but this is the way we do it. It is at this level of description that we can see how the architectural form of the setting in which these activities take place will either support or hinder the accountant at his or her work. Is the desk the right size? Does the lighting scheme allow for clear visibility of the screen? Does the color scheme distract the accountant?

By using these three categories together we can make a bridge between architectural form and the client's goals and illuminate the ways in which specific design decisions can support them.

Ensembles of use

The unit of predictive evaluation, the object of our thought experiment, must, include not only the physical characteristics of a part of the building to be evaluated, it must also include enough description of the use and context of the unit to allow us to relate the physical properties of the part to its role in the whole. For this unit we will use want Richard Hill calls an *ensemble of use* (Hill, 1999).

An ensemble of use is a "specific part of a building and a particular human activity" associated with it (Hill, 1999). It need not have walls, but is a chunk of building that has boundaries defined by either the architectural form or the range of the activity. Hill provides two examples: an employee working in an office workspace, a priest celebrating mass at an alter. In both cases the furnishings and the settling are an essential part of the activity taking place. If the business closes or the church is abandoned, then in Hill's sense the ensembles disappear. An ensemble only exists when specific activities are associated with a specific space. Hill distinguished his ensembles of use from the seemingly similar 'patterns' proposed by Christopher Alexander in that Alexander's patterns are solutions looking for a problem, while ensembles are the conclusion of an analyses of "the relationship between design and usefulness" (Hill, 1999).

Hill is himself skeptical about the ability to use his concept to evaluate designs and buildings, but I believe that by using ensembles as the unit of analysis for out architectural thought experiment we will indeed be able to employ his concept.

Hill stipulates that an ensemble of use is composed of three elements: "a certain pattern of human activity, a certain configuration and detail of architectural form, and a certain arrangement of furniture or equipment." (Hill, 1999) We will discuss each of these below.

Activities

An ensemble of use has "a certain pattern of human activity" (Hill, 1999). This pattern consists of a variety of activities bound together in a practice. Activities being the little things, the physical things, the small-scale actions or tasks, which in and of themselves may not fulfill the purpose of the institution to be accommodated (the client institution) but which are, collectively, and in the context of the relevant practice, the means by which those purposes are fulfilled.

But Hill distinguishes between three sorts of activities: 1) activities which are desired and which contribute directly to the mission of the organization housed in the building; 2) ancillary (tolerated) activities which have little relationship to the mission of the tenant organization, but which people tend to engage in regardless of their primary purpose; and 3) forbidden activities – activities which are harmful to either the organization or the people housed in the building[TD1]. It may be just as important to the success of an ensemble that we discourage a particular activity as it is to facilitate another.

There is a clear relationship between Hill's *activities* and Tzonis' *operation*. Both are intended to draw our attention to the ordinary and mundane activities of users. But whereas Hill isolates the activities, Tzonis speaks of a system of user, activity and form as the operation.

Architecture

An ensemble of use has "a certain configuration and detail of architectural form" (Hill, 1999). This is the physical form of walls, ceiling, and floor, their shapes, materials, and finishes. It encompasses the structural and services aspects of the architectural setting as well as the lighting. The relationships with adjacent spaces are also included in this category.

Equipment

An ensemble of use has "a certain arrangement of furniture or equipment." (Hill, 1999). Taken together Hills' *architecture* and *equipment* correspond to Tzonis' *form*.

Users

As mentioned above, architects have a tendency to design for users who are merely generic constructs (Ellis & Cuff, 1989). "…the 'user' was always a person unknown – and so in this respect a fiction, an abstraction without phenomenal identity." (Forty, 2000) Users thus lack any differentiation, and can have no particular relationship to a building. But there is again a level in between. For every client organization is built up of a collection of people carrying out different roles. If we think in terms of roles, rather than users, we can identify a level of characterization of our users between total anonymity and individuality. Identification of roles also allows for generalization from one client organization to another, from one social context to another. It is then very likely that we can think of specific individuals, known to us who carry out these or similar roles. Perhaps we too carry out similar roles. Much of the physical activity of an accountant is familiar to an architect. In this way we can address two problems, the callousness invited by the anonymity of the term *user*, and the need for verisimilitude.

The Architectural Thought Experiment

Procedure

The steps are simple:

1. Choose an ensemble within the design to evaluate

2. Picture the ensemble. In picturing the ***form*** of our chosen ensemble of use, we are constructing the apparatus of our experiment in our minds. The mentally constructed form of the ensemble is our equivalent of a prototype. This picture must, therefore be both detailed and complete. It must show the "working parts" of our bit of building – the equipment, but also the flow of space, air, light, sound, data, materials, and people through it. Each of these flows will be determined by the combination of physical form and the activities taking place within the ensemble.

3. Imagine someone in that ensemble: what would they be doing? What ought they be doing? What other activities go with the primary activity(ies)? What distracting or undesired activities might also occur there (given the primary and adjunct activities)?

4. Now we must list the activities that will take place within it. These fall into three groups: the planned activities (those activities the housing of which is our purpose in constructing this building), the acceptable activities [check Hill's terminology], and the unacceptable activities. Our goal is to encourage, and enhance the planned activities, to allow for the acceptable activities, and to discourage or make inconvenient and unappealing the unacceptable activities. Of course what is planned, acceptable and unacceptable depends on one's point of view. We must therefore explicitly declare for whom we are conducting this experiment.

5. Now instead of a 'person', a bland unformed creature from your stock of architectural figurines, picture someone you know in the ensemble. Choose someone who does similar activities, or is engaged in a practice similar to that for which the ensemble is being designed. By picturing someone real, you lend greater verisimilitude to the experiment. You can now repeat steps 4 and 5 building up the realism of the experiment, getting more of a feel of how a real person might interact with the designed environment.

6. What would this person you have imagined need to carry out their primary activity? Would this person need to use any required equipment, or engage in any required collaboration (with whom)?

7. Are these conditions, equipment, etc, present or available in the ensemble as it has been designed? What happens if we vary aspects of the design? (E.g. lighting, dimensions, enclosure, colour, materials, …)

8. Now vary the conditions. Imagine the form or furnishings of the ensemble to be different. Different lighting, different time of day, different materials…. How does this affect the person and their engagement in their activities?

9. Draw conclusions: design is good, or bad, and what ought to be improved.

Results

As Christopher Alexander noted mis-fits are much easier to identify than fits (Alexander, 1964). That is to say that it is much easier to identify aspects of the design that don't work than it is to list requirements of things that do work. The relative ease with which mis-fits can be identified makes the search for mist-fits especially valuable for our thought experiment. Of course, one could also point out that in cases where there is only one design scheme being evaluated, things that are not broken do not need to be fixed.

Thus the first set of results to be drawn from the thought experiment are about aspects of the design proposal that must be changed. However, the thought experiment will also tend to suggest solutions to these problems as well. By varying the form the designer can weigh different design solutions against each other. In addition, the thought experiment yields reasoning and arguments as well. This can be particularly advantageous for working with complex clients where the design decisions must be referred back to senior management, and it is therefore helpful for the designer to present his or her clients with arguments for the proposed design scheme, and in particular for design decisions that are controversial or lead to increased construction costs.

Envisioning

Serendipitously, as I was preparing this paper, while interviewing an architect for another research project, learned that he does very much the same sort of thing that I am proposing here. He[4] calls in *envisioning*, and in his firm he uses this technique to work out how spaces will work. I conducted a second interviewed with the intention of discovering what his practice was. What emerged was that while he has an extremely considered means of designing in his firm, based on dialogues between himself and his associates, he was unable to describe the envisioning process in concrete procedural terms. What did emerge was that for him envisioning is a process in which architectural form and the social conventions governing the behavior of the future users are brought into view simultaneously. He claims to work very quickly, to conceive the parti of a project based on a repertoire of relevant social conventions. This parti contains sufficient information to govern how it will be worked out. In this process of generating the parti there was an intimate connection between social convention and building form. Neither comes first.

This repertoire consists of his personal collection of both tacitly and explicitly acquired impressions of buildings. He is always observing, looking, around him, recording how every building works and what people are doing. This repertoire of observed forms and social conventions is central to his method. His ambitions are

[4] He is the principal architect of a medium sized firm with an international reputation and a portfolio of single family and multi-unit housing and small institutional buildings.

to communicate with his audience (the users of his buildings) rather than to confront them as was typical of the avant guard-ists. Thus he treats everything he sees as potential material to be incorporated into some future design.

He is quite fluent in discussing the general atmosphere of the spaces he designs, and the broad activities of the occupants, but while his designs are highly refined in both aesthetic and functional senses, he does not articulate an explicit process of working out how people will move around a bar, for example.

Perhaps the most striking thing about his design process as he related it is that the process is linear, always moving forward, rarely requiring that decisions made be changed or unmade. He says of his models that they are not means of checking his design decisions but means of propelling the design forward. In the terms of design methodologists, there is no evaluation. He does what we are all taught not to do as students, what we all advise designers not to do – design forward form his initial impressions of the site to the finished construction drawings without looking backwards or revising.

This is, I believe, a highly developed, yet still largely tacit approach. Envisioning bares similarities to the architectural thought experiment in that it emphasizes the association of activity and space. It clearly serves this architect well, but might not be a method that can easily be taught or learned, other than by working in his or a similar firm. Further, he acknowledges that it is often himself that he sees (or perhaps better is seeing) within the imagined spaces rather than the people he is designing for.

Envisioning relies on a very robust ability to generate successful design solutions. Not every architect will have such a robust ability. Yet, what his method does demonstrate is that if one "think[s] about things a long time, very, very thoroughly", referring to one's repertoire of conventions, one can gain fairly reliable picture of how people will receive one's designs.

Where envisioning differs from the thought experiment is in the implication of a cyclical approach to design and in the presence of a moment of formal evaluation in the design cycle. The structured approach not only helps to provide the architect with explicit arguments for his or her designs, but may also provide the client with confidence that the architect has carefully considered their needs.

Conclusions

Suggesting a method to designers, especially in this rather hypothetical form seems to be a little audacious. Designers are currently seldom interested in explicit methods, and currently often seem to privilege aesthetic interests over a fine appreciation of how users interact with buildings. Yet I think that the architectural thought experiment proposed here can be of value to architects, clients and architectural instructors.

I propose that we consider the thought experiment much as an athlete or coach considers technique. Even at the top levels of sport, perhaps there most of all, coaching proceeds my analyzing the performance of athletes, determining how to improve their technique, then teaching them the new movement in pains-taking and explicit detail. This often leads to a temporary decline in performance while the athlete has to think about what he/she is doing in applying the changed technique, but as it is gradually incorporated into the way the athlete moves, the 'thinking' falls away and the performance improves and exceeds the previous best. Thus the thought experiment is not something one must always do, rather it is like a technique, to be practiced until it goes away, leaving an improved but once again largely tacit practice.

Like the athlete, the designer functions best when not thinking about what he or she is doing (Lawson, 1980). Yet by practicing the thought experiment as described here, designers may be able to learn to visualize their design proposals with increased detail and verisimilitude, and inform their mental homunculi with characteristics that the future users of their buildings may share. They may also gain an increased ability to convey to their clients the reasoning that justifies their design decisions and the arguments which lead them to anticipate that the client will be satisfied with the resulting building. If such benefits can be realized, then once they are internalized the formal procedure may no longer be necessary, and the architect, like Wittgenstein's students, may through away the ladder that enabled him or her to ascend to the new level of insight.

References

Alexander, C. (1964). *Notes on the synthesis of form*. Cambridge: Harvard University Press.

Brand, S. (1997). *How buildings learn: What happens after they're built* (Rev. ed. ed.). London: Phoenix.

Ellis, W. R., & Cuff, D. (1989). *Architects' people*. New York: Oxford University Press.

Forty, A. (2000). *Words and buildings a vocabulary of modern architecture*. London: Thames and Hudson.

Hill, R. (1999). *Designs and their consequences: Architecture and aesthetics*. New Haven [Conn.]: Yale University Press.

Kuhn, T. S. (1977). A function for thought experiments. In T. S. Kuhn (Ed.), *The essential tension: Selected studies in scientific tradition and change* (pp. 240-265). Chicago: University of Chicago Press.

Lawson, B. (1980). *How designers think*. London,Westfield, N.J.: Architectural Press; Eastview Editions.

Mach, E. (1976). *Knowledge and error*. Dordrecht: Reidel.

Polanyi, M. (1967). *The tacit dimension* (Anchor Books ed.). Garden City, N.Y.: Doubleday.

Tzonis, A. (1992). Huts, ships and bottleracks: Design by analogy for architects and/or machines. In N. Cross, K. Dorst & N. Roozenburg (Eds.), *Research in design thinking* (pp. 139-164). Delft: Delft University Press.

Winograd, T., & Flores, F. (1986). *Understanding computers and cognition: A new foundation for design*. Norwood, N.J.: Ablex Pub. Corp.