8 Possibilities for education and study

8.1 Education

Entering a new culture

Education introduces people to a new culture. A culture is a set of shared suppositions. If your students do not share any of the suppositions you to start with, then your teaching will fail. If there is not a sufficient common culture (such as a common language, a shared distinction of subjects, some awareness of their relevance, their separations and connections, some values of mutual behaviour or other self-evident background such as primary mathematics), then there is no basis for successive advancement for the next steps. Without the preceding suppositions you usually take for granted yourself, you cannot expect your students to understand the next conditional, logical or causal step, because it is based on preceding steps. They will not ask you about your tacit background, because they are either (wrongly) ashamed, or simply because they *cannot know* what to ask (Meno's paradox). They will miss a step and stay behind.
Education requires a conditional sequence of steps.

The art of educating

The art of educating is the art of recognising your own tacit suppositions. Some of your suppositions that are essential for the course, may be different from those of your students. Omitting bridges between concepts, or ignoring gaps or barriers, results in a silent misunderstanding or loss of attention and interest. It is not easy to estimate what your students suppose rightly or wrongly, and what they do not suppose at all. Telling what everybody already supposes is as disastrous as not telling what has to be told first. In the classes that contained students from many cultures, I used to count how many students yawned and how many had glazed looks, and I would accelerate or slow down my lecture accordingly. It is of course better to let them speak, write or draw first, and carefully examine what each of them may miss, avoid, or wrongly suppose. But that is time consuming, and not easy. Students may be inclined to avoid the gaps and barriers by applying safe, traditional solutions, without even being aware of other possibilities. You, then, still cannot conclude what they miss or wrongly suppose to be able to solve *non*-traditional problems, and to find *improbable* possibilities. Some wrong suppositions may be hidden so early in the conditional sequence of suppositions, that you even cannot imagine them yourself.

A conditional sequence of suppositions

Even if you are fully aware of the suppositions you do not share with your students, you still have to explain them in the right sequence. In specialised disciplines it is easier than in a design education to know what you need in the Bachelors to be able to understand and to succeed in a Masters program. *Design* education requires you to *integrate* the contributions of many specialists that speak many different (mainly linear) languages. It requires a student's *awareness* of their existence, their field of knowledge and know-how (without sharing with them completely), their relevance in different cases and an *ability* and *daring* to ask specialists the right questions, and to express her or his doubts in *their* language. Their possible contribution, their jargon and the relativity of their advice may be obvious for you, but not for your students. They may take them too serious or not serious enough. It is difficult to find a balance between too little details to keep in touch with specialists, and too much details to maintain an overview perspective. And, a design is much more than combining specialist contributions. It requires a *productive* mode of thinking, which is very different from the specialist's *reducing* possibilities into truths and probabilities. A specialist cannot make this switch easily after years of education, and also because they are respected just *because* of her or his authoritative knowledge in a field of proven truths and probabilities. The core of *design* is to imagine possibilities *beyond* anything existent or probable. How to teach that kind of imagination? Imagination in and of itself has a conditional sequence of suppositions. It starts by *distinguishing* things that are imaginable next to each other in time (to find *causes* that make things probable) or in space (to find *conditions* that make things possible). This thesis may have given some suggestions for spatial distinctions: distinguish outward and inward directions, distinguish levels of scale, and distinguish what is probable from what is possible. But, let us first clarify the time- and action-based specialist expertise that should be transferred to an education of designing the *environments* of action.

Truth finding by specialists

'Knowledge' is a set of tested suppositions about limited parts of reality. In a pragmatic sense, suppositions are called 'true' if they repeatedly have supported our intentions and actions better than previous suppositions. Scientific knowledge convinces best, if the knowledge is the most successful basis of economy, culture, education or even justice, and if it enables more people to survive than ever before. The empirical method of truth-finding is convincing through the social success of:

1. concentrating on isolated, conditioned, but repeatable observations,
2. freely generalising them in readable suppositions,
3. freely publishing both in a refutable way,
4. to be checked freely under the same conditions by other people.

Empirical research may falsify useless or even harmful suppositions as 'mistakes', 'misrepresentations', 'myths' or even 'lies', showing ignorance, credulity or even deceit. Education should particularly challenge these suppositions. But, compared to the inconceivable diversity that *could* be observed, scientific knowledge still covers a tiny selection of reality. The possibility of generalisation outside this selection is commonly accepted, but it is only a shared, repeatedly successful supposition. The selection itself is influenced by existing categories of communication, words, and variables. The inward categorisation of the initially observed diversity, and its outward generalisation into other contexts, have become suppositions that are silently recycled in any empirical cycle. You cannot easily criticise suppositions other than using those categories. Your criticism beyond the common vocabulary cannot be understood. The critique then often remains immanent. You cannot easily withdraw from these tacit categorisations and generalisations in a deafening acoustic feedback of commonly accepted citations.

Inward specialisation, outward generalisation

Differences are generalised in words, language and theories *as if* they were equal, waiting for the next falsification by new observations. The 'same' atoms appeared to be different as isotopes. The 'same' molecules appeared to be different *drawing* them as isomers. The 'same' species appeared to be different as subspecies, races and characters if you took a closer look. Any discovery is focused on distinguishing more differences mainly *within* existing categories (immanently)[a], raising more questions about their relations, and more problems to be solved by an ever larger multitude of specialised disciplines. These disciplines continuously have to extend their nomenclature. After 3000 years studying our own species we now need at least 29 medical specialisations, and still, we 'know' little about ourselves. With our increasing knowledge, our awareness of what we do *not* know seems to increase. Scientific effort is motivated as 'truth-finding'. But, what is 'truth' if it is not

[a] Kuhn(1962) *The structure of scientific revolutions* **IN** Neurath, O.; Carnap, R.; Morris, C. *The International Encyclopedia of Unified Science* (Chicago) The University of Chicago Press

complete? Without specified context, and its scale (ceteris paribus), it is 'half truth'. If 'context' encloses every level of scale, then even anything differs, and generalisations that ignore context may become doubtful for designers in practice.

Possibility search by design

Incorporating the contributions of every specialisation involved in a design, requires 'possibility-finding' *outside* their limited subset of 'truths', or their approximations, called 'probabilities'. The larger set of possibilities, however, is even more diverse than its subset of probabilities. The usual categorisations of scientific knowledge that are expressed in generalising words, and in strictly sequential texts or theories, do not provide a sufficient understanding that allows designers to find new possibilities. To invent new possibilities, you still may use many existing suppositions, otherwise you get lost. But, creativity is *skipping* at least one commonly shared supposition. It may open a view on what is behind that barrier. Design education then should include exercises skipping common suppositions. Carel Weeber once assigned his students to design a customs office on the Moon between two countries inhabited by people of substantially different size. Skipping usual suppositions (e.g. about size, gravity, day length, light and atmosphere) is required to liberate imagination.

A dialogue with your drawing

Imaginable objects cannot always be expressed fully in a linear language with equalising categories connected by verbs. If we restrict ourselves to spatial design, then a two-dimensional drawing shows relations perpendicular to the direction of a linear representation: the side roads and views from its main road. The character of side roads, side views and their possibilities may be different, contrasting, opposite or even contradictory to the main course of a text. That pictorial con-text shows the many *possible* relations of different kinds and scales. You primarily discover and invent them by the act of drawing itself. Expressing your imagination in a drawing produces unexpected effects that were not yet present in your previous imagination. You may improve it, emphasise some, and weaken others. The motoric act of your hands may add tacit suppositions to your idea. Mistakes may become advantages, as mutations did in evolution. The feed-back from what you expressed in a text or a drawing may change your thoughts about possible processes and patterns. A text *tells* a story, but a drawing *accommodates* a multitude of possible stories. The feed-back of drawing is two-dimensional, multi-directional, but scale-bound. From a viewpoint of improbable possibilities, usual categorisations may shift through the act of drawing. In an initial drawing, their boundaries may change into non-verbal distinctions not yet specified by words or a legend. This is the creative point where you may skip usual suppositions about content, form, structure, function and intention.

Conditional sequences of imagination

It has taken many years before you could imagine a possible reality behind a design. The number of suppositions you have built upon each other to reach this level of imagination exceeds the number of words in your vocabulary. Piaget's 'tableau mouvant' of differences, and different changes you probably have experienced shortly after your birth, still had to be separated into objects that were moving faster than their relatively stable background before you could connect words to them. Your first year must have been filled with parallax experiments to connect your experience of own *movements* with the changes you could *see*. This connection should have been constructed before you could distinguish separate objects nearby and further away. Your recognition must have been developed by connecting returning objects with the objects you remembered as imaginations, even if they were absent. These imaginations subsequently must have been connected with the returning *touch* and *sound* experiences that accompanied their appearance before you could *grasp* them by your own movement, and name them by the same *sound*. Many more conditions must have been fulfilled before you could simulate your touch by drawing them. Drawing supposes coordination and *direction* of movements to grasp what you have in mind, and to select what you want. Selection supposes (⇓) connection ⇓ separation ⇓ change ⇓ difference, to name only *some* necessary conditions of imagination (see *Fig. 222* on page 242 and *Fig. 240* below). You have constructed your imagination step by step, by passing these stages your own way. You have simulated your progress by building towers and playing with blocks. You may have experienced how difficult it is, to change the lower blocks to make a larger tower possible. Changing suppositions is at the core of design-education's aim of expanding a student's power of imagination.

influence ⇓	production ⇓	selection ⇓	probability ⇓	management ⇓	intention ⇓
involvement ⇓	organisation ⇓	connection ⇓	possibility ⇓	culture ⇓	function ⇓
identity ⇓	specialisation ⇓	separation ⇓	**imaginability**	economy ⇓	structure ⇓
expression ⇓	regulation ⇓	change ⇓		technique ⇓	form ⇓
imagination ⇓	consumption ⇓	**difference**	(overlapping)	ecology ⇓	content ⇓
			desirability	**space**	**scale**
Conceptual ⇓	*Biotic ⇓*	*A-biotic*	*Modes*	*Layers*	*Orders*

Fig. 240 Outward conditions

Fig. 241 Inward conditions

Modes of reason in a conditional sequence

Fig. 241 shows other selections from the numerous suppositions you once may have passed in a conditional sequence. They are chosen as other milestones, placed in the same sequence as they are used in this thesis for different purposes. The sequence is determined by a simple introspective test: 'could you imagine A without B, but not B without A, then B is supposed in (or conditioned by, made possible by) A'. Since it is necessarily an introspective test, the right sequence is open to discussion. It would take a long time to put any pair of words, categories or even non-verbal suppositions to this test, but the sequences given in *Fig. 240* and *Fig. 241* may be used as preliminary checklists for education. The terms printed **bold** are starting points that do not require further suppositions. I cannot imagine probable futures without possible ones, but I can imagine possible futures without probable ones. It is even the task of designers to imagine improbable possibilities. Possible futures are not imaginable if you cannot imagine them, but the boundaries of imagination cannot be drawn, because in that case you would have to imagine what is outside the imaginable (an argument derived from Wittgenstein). But, you can establish that some people possess more imagination than others. Imagination can be extended. For design, however, they also have to be limited to what is possible, and this can be concluded only by realisation. The fourth mode of desirability overlaps probable and possible futures (see *Fig. 2* on page17), sometimes even exceeding the possible as an imagination of the impossible.

Layers of function in a conditional sequence

The 'layers' of *Fig. 241* express a sequence of 3 social layers, supposing 3 physical layers in a conditional sequence of 'functions', as assumed in section 6.3 on pages 225, 229 and 230. A failing management may indicate a failing execution of its tasks, but it also may indicate lacking underlying conditions to fulfil these tasks: a lack of culture, economy, technology, ecology or space. I cannot imagine a management without a set of shared suppositions (authority, appointments), a culture. I cannot imagine a culture without a sufficient economic basis to survive. I cannot imagine a modern economy without an operational technology, a supporting ecology, enough space, time and materials. You may object, that it is the very *task* of any management to manage and to take care of these functional conditions. But, this *probable* downward *causal* effort (see *Fig. 242*) is only *possible* by a minimal fulfilment of functions in an upward *conditional* direction. Moreover, these conditions determine the *priorities* of management prior to the execution of its plans. A manager may conclude that the 'culture' of an enterprise does not function according to its aims. (S)he then may propose cultural measures to improve its performance. But, if the employees use outdated computers or machines in ill-ventilated, dark and narrow rooms, a manager may better improve these preceding conditions first, before accentuating less basic demands.

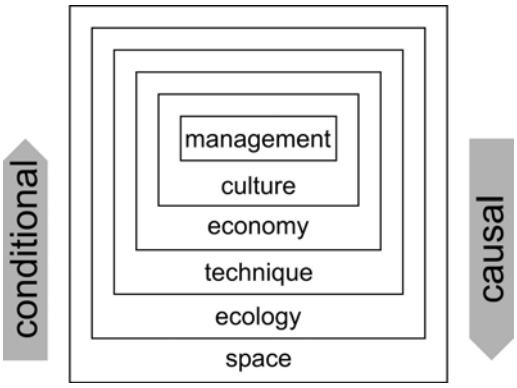

Fig. 242 Layers inward and outward

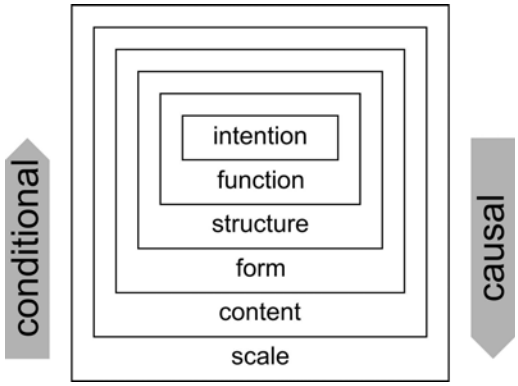

Fig. 243 Orders inward and outward

Orders of difference in a conditional sequence

A spatial designer must be aware of these functions, but it is not the task of design to determine them by *causal analysis*. Rather, it is their task to make them possible through *conditional synthesis*. This switch from reductive analysis into productive synthesis is apparently so difficult, that these tasks are divided between managers and designers. Managers are specialised in talking, time, *changes*, strategies, tactics and flow schemes. Designers are specialised in drawing, space, *differences*, conceptions, types, scale-models. But, just as managers have to be aware of *conditions* to choose their priorities rationally, designers have to be aware of *causes* to decide how to start designing in a given context. A designer has to cope with a *field* of problems (usually covering a larger time span than those of management). (S)he has to find a direction in that field, balancing between future needs and possibilities (see 7.1 on page 245). Some of the problems may be solved better at an other level of scale than the assignment suggests. That could change the assignment. “Why a canteen if there is a restaurant next door?” “Why a central garden if you can make a green balcony for every room?” Possibilities can change needs. Designing is not merely following the required functions stemming from traditional imaginations of probability specialists. It also may produce possibilities that change the intentions of the client. There is an inconceivable diversity of possible contents, forms and structures to choose from. Many of them can serve the same brief. Any of them adds affordances that are difficult to formulate in words. They may become important as soon as the client has to change its use or to sell the object before it has to be demolished. Some multi-functionality improves a building’s resale value and client attraction. But, even for a brief with a very strict programme of functions, there is still an inconceivably larger diversity of possibilities than the available traditional solutions. How to cope with this diversity? In the daily practice of design, with its time pressures, it may be wise to start analysing the intentions of your client and its traditionally formulated functions, to study some successful existing examples and to combine their partial solutions into a new solution fitting the given context. You may even decide to join a building industry to limit your design possibilities further into the most economically executable solutions available, offering the client an ‘integrated design’. It is the ‘causal’ way in *Fig. 243*. But, is it also the best way for design *education* aiming to extend their students’ ability to explore possibilities, and improve the power of their imaginations? The content of this thesis follows the opposite way to stress imagining possibilities instead of probabilities.

Design methods

Your design starting point may differ in different social and physical contexts of design practice. It may result in a different design method each time. If the location, the required functions and the intentions of your client are strict and clear, then the ‘functionalist’ approach may be the best. If the form simply follows the stereotypes of function according to the imagination and expectations of your client, then it is also the least time consuming method. It avoids risks. It becomes innovative if you deviate from these stereotypes, or if new functions appear. Even a functionalist designer has to explore the other possibilities of structure, form and content, if there are no examples. The 'structuralist' way is mainly motivated by the intention to relate to the human scale. It aims at a particular kind of structure: smaller separated parts connected into a whole. It starts lower in the sequence of *Fig. 243*. But, if it does not pay much attention to these separations and connections in the beginning, then it starts even lower. It then may be named better as 'compositional design', because it starts studying a 'form' that is clearly articulated in components at a human scale. In practice, you may choose any level of *Fig. 243* as a starting point, depending on the context. But the higher the level, the more tacit suppositions about the lower levels play a role, and education should start with the least number of suppositions possible.

Design education starting by scale and content

This thesis suggests to start exercising design at different levels of scale, e.g. R = {30, 10, 3, 1, 0.3, 0,1km}. An exercise to make them all successively, will make students aware of the different content of each level of scale, expressed in a slightly changing legend. Suppose, you divide 20 students into four sector-groups called 'Red' (housing), 'Green' (nature), 'Yellow' (business) and 'Black' (infrastructure). You lay down a plasticised 2.4 x 2.4m map, representing a region R=30km (see Fig. 245). You give each group stickers r=1.2cm (300m) in their colour. The number they get fits the expected extensions in the region for the next 30 years. Any sector group gets 3 minutes in turn to glue their stickers on the map according to the interests of their sector, until all are used (see Fig. 244).

Fig. 244 *Students making a dot map 1:25 000 2030 with stickers r=1.2cm(300m in reality).*

Fig. 245 *The R=30km region Veluwe-Arnhem-Nijmegen to be filled with dots*[a]

Within one hour, the result is a 'laissez-faire map' of the region, filled with the extensions you may expect if there were no planning. The students evaluate the result and write down the general impacts, and the impacts that are specific for their sector. The next day they meet to discuss what they have to study to make a better plan next week, and divide the tasks. They make alternatives for their own sector, in order to discuss them with the other sectors. At the end of the week, they meet again to choose the best fitting sector alternatives, and to discuss how to make a better plan through coordinated planning.
The next week you repeat the exercise, resulting in a *planned* design for the region. Every student makes a personal report comparing both plans, and chooses an R = 10km part counting the glued surfaces, in order to make a more detailed design according to these surfaces for that part individually. The individual R = 10km plan is detailed until r = 100m (the grain of the drawing), with a further differentiation of the legends. Every student presents her or his plan in the third week. Next to that plan they make a report of the problems they met,

[a] CityDisc(2000) Den Haag

and criticise the decisions of the previous R = 30km regional plan.
This procedure is repeated in week 4, by detailing R = 3km until week 7, where they detail R=100m. After 7 weeks, every student has made 5 designs at different levels of scale evaluating and criticising their previous design decisions, and developing the legends appropriate for different levels of scale.[a]

Design education of possible content and form

The dot map of Fig. 244 shows how 'form' can be interpreted as 'distribution in space' of some content. *Fig. 74* on page 114 shows possible contents as spatial variables with values at different levels of scale. The columns of the table show which variables may deliver values useful as legend units in a radius R = {1, 3,…300m, 1, 3,…300km}. There are, however, many more spatial variables possible, and there are singular legend units not fitting in an ordinal range to be named as a variable. A variant of the exercise above uses other predefined, but rather unusual legend units to obtain a different interpretation and image of areas at different levels of scale.[b] A simple exercise that would stimulate imagination begins with choosing a radius, an existing area of that size, and two suitable variables, in order to make a design that varies the values of these variables. The design thus will have a legend based on these variables. You may ask several questions about such a design, e.g.:

- Are the successive values of one imaginable variable gradually changing in space?
- Could you imagine more legend units as values fitting in the same variables?
- How could you describe the environment *between* any pair of legend units?
- How many kinds of boundaries are possible, and how many are realised?
- What is their length compared to the shortest length possible (boundary-richness)?
- What is the character of these boundaries (see *Fig. 52* on page 98)?
- Is this character direction-sensitive?
- How could you describe the distribution in space (see *Fig. 95* on page 161)?
- What is the total and average surface covered by any legend unit?
- Are the possible distributions limited by the character of the variables?
- Is there an implicit or possible relationship with other variables?
- Could you identify different components in the composition of the drawing?
- Could you characterise these components (see *Fig. 65* on page 102)?
- Does this characterisation suggest other variables of a larger scale?
- Could you draw some characteristic and connecting details (*Fig. 65* on page 102)?
- Would the distribution and composition be stable without additional measures?
- Which connections and separations would you propose between any location?
- Is the distribution in space as proposed in the design operational for any use?

You may add questions about the distribution of lines (see 0 from page 164 onwards).
If the design concerns the smaller radiuses R = {1, 3,…300m), then the third dimension plays a crucial role. The vertical direction may show other variables than the horizontal ones. You may extend the number of variables of the exercise.

Design education of possible form and structure

A composition divided into components and details may suggest 'structure', but structure as intended in this thesis has to be distinguished from 'composition'. It is an additional set of separations and connections to stabilise, to realise and to use the form in the sense of 'construction'. It deserves separate attention concerning potential movements, such as collapse or other undesired flows that disturb the form and its use. Structures in three

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[a] An elaboration of this exercise in Dutch is downloadable from http://team.bk.tudelft.nl/Publications/2001/Jong(2001)ModuleGrondgebied(Delft)BkUrbanismS4.pdf.
[b] A variant of this exercise in English using predefined legend units is downloadable from http://team.bk.tudelft.nl/Publications/2002/Jong(2002)DesignAndTechnique(Delft)BkUrbanismMSc1.pdf.

dimensions introduce detailed problems of mechanics and physics of flows. They require necessarily specialised parts of design education. But, they include structures already present and imaginable in a two-dimensional drawing through plain maps, floor plans and cross-sections, which are ex-*plain*ing the third dimension. Design education suffers from the idea that a larger scale is more complex than a smaller scale (closer to the daily experience of students), but it is not. 'Structure' in particular is not part of daily experience. To become acquainted with structure, the larger scale may be even more simple and appropriate. The resolution of understanding at a larger level of scale preliminarily neglects the complicating third dimension. Two-dimensional imaginations and problems are less complex compared to three- and four-dimensional ones. For educational purposes, it then may be wise to study the relationship between form and structure in the two dimensions that are dominant at a larger scale first. Moreover, the larger scale is the context of any spatial design object, a source and destination of its functions and intentions, and the source of its brief.

Structure in two dimensions

Structure in two dimensions at a larger scale is the separation from or the connection with (the exposure to, or resistance against) sun, plantation, energy, wind, noise, water, traffic, earth, cables and pipes, living nature, nature preservation, other people, environment in general and so on. You cannot study the impact on, or from, an object without knowing its content, its distribution in space, its form, exposure to or influence on these factors. You cannot calculate light and shadow, the behaviour of wind, water and so on without a preliminary design. Structure *supposes* a lay-out to study the possibilities of separations and connections. Structure thus can be taught best through asking questions about examples, or a student's preliminary design. A structure stabilising a *concentrated* form will be different from a structure stabilising a *dispersed* form, in regards to making them operational. A concentrated form may require more separations; a de-concentrated form may require more connections. Space separates passively, demanding expensive connections such as roads, rails, cables, pipes and the time for transport. But, concentration requires sophisticated solutions to combine separations and connections. Connections require separations perpendicular to the connection, resulting in elementary devices combining them (selectors, see *Fig. 8* on page 29), and separations require connections perpendicular to the separation. Different networks of connections may interfere (see *Fig. 104* on page 166). A student's preliminary design can be the basis for an exercise to study these effects in space, asking questions such as: "What did you do with sun, energy, plantation, wind, noise …" and so on. The students should dispose of computer simulations (see *Fig. 246* and *Fig. 247*)[a] to determine these effects in a given design directly, without complex mathematical effort, but with sufficient background information.[b] The calculations can be simulated appropriately in Excel with a little programming in VBA using sliders. Excel is available at many computers and the sliders enable one to choose an input *and* an output of the calculations simultaneously. Sliders enable the student to choose an output to find the right input. Such calculations are not intended to replace specialist advice. They enable designers to experiment, to ask the right questions in the language of specialists, and to make them less vulnerable in their company. The students become aware of the parameters (their names) involved in the calculations, of the behaviour of sun, wind, water and so on, in the designs made by themselves. Now you can ask them the same questions concerning how they will use the achieved knowledge in future designs.[c]

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[a] Sun .xls; Energy .xls; Wind .xls; Windvelocity(heigth) .zip; Wind behaviour of parcellations .xls; Sound and noise .xls; Water.xls; Trafficnetworks .xls; Earth .xls; Earthquakes .xls; Life .xls; Butterflies dispersion .xls; Human population .xls; Living .xls; Standard allottments .exe; Environment .xls, downloadable from http://team.bk.tudelft.nl/ > Publications > 2009

b Jong(2009) *Sun wind water earth life living, legends for design* (Zoetermeer) lecture paper, downloadable from http://team.bk.tudelft.nl/ > Publications > 2009

[c] Examples of such exercises may be found at http://homepage.tudelft.nl/q7q71/ , http://homepage.tudelft.nl/1n01y/ , www.mmap.lt/viktorija , http://homepage.tudelft.nl/y71r1/.

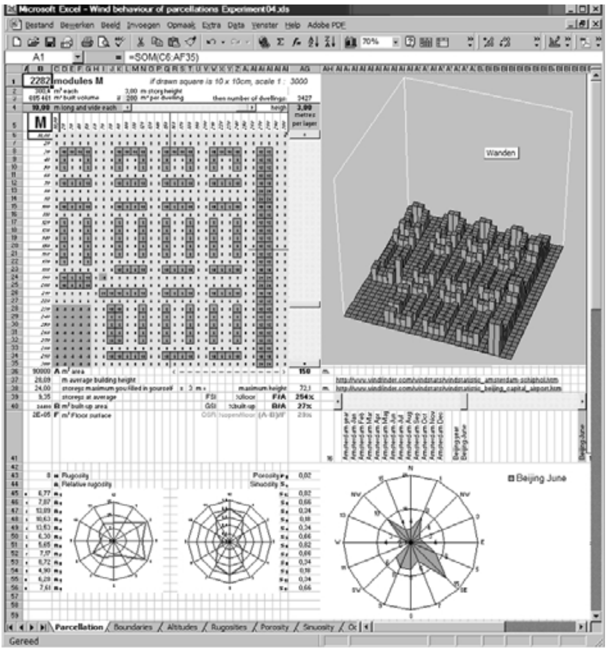

Fig. 246 R=100m Simulating wind

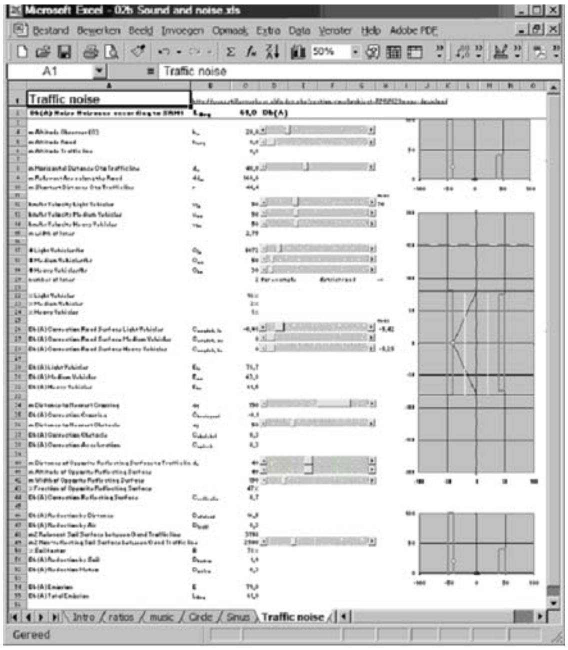

Fig. 247 R=30m Simulating noise

Structure in three dimensions

There are many dispersing effects to be prevented or compensated by separations and connections, such as the sprawl of cities, flood, and noise. Examples of passive *separation* by space in two dimensions can be used to introduce the thermodynamic principles of distribution, separation and entropy in three dimensions. The third (vertical) dimension subsequently adds the passively *connecting* effect of gravity, perpendicular to the horizontal plane. This plane already has shown the spatial *separation* and sprawl, probably compensated by high rise building, and *connected* to the ground by gravity. But, gravity is a different kind of connection (see *Fig. 71* on page 105). It does not connect different locations by dynamic flows; it connects piled up building materials by static force. It causes a vertical concentration of matter with an inclination for horizontal de-concentration demonstrated by the collapse of a building, the erosion of mountains, and the runoff of water. It introduces mechanics. The application of mechanics and thermodynamics at the smaller scales require a specialist's education. I will not elaborate on them further, because they are well developed.

Structure and operation, four dimensions

The fourth dimension (time) could be elaborated for education as 'difference of change'. Time is already silently supposed in the previous exercises as change by design, as flows at the Earth's surface, and as potential change by collapse. Different changes have enabled us in our first year to construct a third dimension by exercising parallax (see page 263).
But, this is not sufficient to understand differences in changes in the three-dimensional *operation* of a structure and its functional *performance*. Directing a flow in a pipe or through a gutter supposes a difference of change. Stable solid matter directs moving gases or fluids. But, even the solid matter of the pipe or the gutter changes in the long term, by breaking down. Their difference in change enables their current *operation*. If the water within a pipe freezes, then its operation will stagnate. The functional *performance* has its own time span, which interferes with the time span of the solid matter and the directed flows. If water needs increase over the years, the flow speed or quantity may become insufficient. A house is a stable device that enables the directed movements of people, furniture and commodities, and protects them against external changes. A town is a device that enables fast movements and dynamic processes next to stable structures to stay in rest. In the long term,

the elements of a town change at different paces. From ecology, we learn that sudden measures to rescue or restore an ecosystem may destroy it, by surpassing its own adaptation speed. *Fig. 226 The costs of increasing knowledge and reducing risks* on page 248 shows the problem of time-balance, as it appeared in the region of Adapazarı. The problem is known in management techniques, but as far as I know, not precisely elaborated in technology. Bio-mimicry may inspire technology by examples from living nature, but I do not know studies about grades of structural stability in nature, except some branches of ecology. Living tissues move with the processes they support, membranes even take part in these processes without losing their coherence. How to exercise the ability to imagine differences of change at different levels of scale? I do not know, but I suppose that they may be essential in future design education.

Typical functions

The use of an object of design is up to the users. A small part of this use is imagined and intended beforehand, and this may be represented in a brief. But, the actual use is only a part of a much wider 'function'. Any object will function at different levels of scale and in different time spans. You may use a theatre to see a play, but passengers outside the building recognise it as 'a theatre', and citizens know it as 'the theatre'. The longer the object will exist, the less predicable will be its final function in different periods, and at different levels of scale. You may refer to 'tacit functions' if they cannot be predicted, desired or even imagined beforehand. The designer's task is not to *determine* functions, but to make desirable, eventually tacit functions *possible,* and to avoid undesirable ones. As a functionalist designer, you will start with the brief, which is mainly represented in words and figures. The nouns in the brief are well-known categories (sets), referring to many examples. As a designer, you may study examples that have functioned similar to the client's intentions, but you cannot copy them.

Types, combinations of incomparable categories

If different examples show similar forms or structures, then you may have found a 'type'. A type is a combination of incomparable categories such as form and colour. An object cannot be more cubic than blue. A cubic, blue object thus is a type. Form, structure and function are also incomparable categories. An object cannot be more cubic than strong or stronger than useful. A half-round theatre thus is a type, a subset of at least two categories (sets). A type may get a name (amphitheatre), but it is a combination of well-known categories, an intersection of sets. A type is something in between a noun (referring to a category or set) and a name (referring to one particular unique object). To identify a unique object by words, requires adding as many suitable categories (expressed in adjectives or subordinate clauses) as necessary to indicate just one particular object. The study of types (typology) in design science may reduce the effort of functionalist designers to choose between an inconceivable amount of forms and structures that make the same function possible. A catalogue of previously built theatres may show different types of theatres with a similar form and structure being characterised as 'amphitheatres'. Choosing one of these types saves time, because it is proven to be possible. It makes the result recognisable: "Typically a theatre!". But, some questions may arise:

- Is it still possible (suitable) in the current context?
- Is the characterisation of examples the only one possible?
- Could you choose other groupings to typify them?
- Are there other examples that do not fit in any known type?
- Could you invent a new type, without any previous examples?

The function of a theatre is rather clear, but it may be combined with other functions such as a restaurant. And then, there are theatres where the meals are served while you are looking at the performance or during the breaks or even during the performance, producing different types. And, there are even more multi-functional devices such as a dwelling, a neighbourhood, a town (…the world). Summarising their possible functions gradually becomes a hopeless task. In such cases you may start the other way around by looking for forms that intuitively fit at the location, imagining different uses and functions amongst which surprisingly the required one is also included. I know two educational exercises that enable designers to cope with functions. The first exercise was invented by Hertzberger, a famous architect, but surprisingly, also an excellent teacher in architecture. Let me refer to his text[a] and summarise this educational method in four points only:

- Break off your clichés;
- Collect as many examples as possible;
- Put them in a different context;
- Combine, leave out, adapt.

It starts by an attempt to skip usual suppositions (clichés) to create space of thought. This enables looking without presupposed categories or types, the next step. But, I would advise to be a little bit selective avoiding mono-functional examples. If you take e.g. predominantly multi-functional objects such as dwellings, then you may leave out elements of form, structure and function to obtain a theatre, a school or a hospital. The strongest point, however, is the advice 'Put them in a different context'. It forces you to skip *and* add suppositions about the context. It makes you aware of its levels and layers.
The second exercise is invented by Tzonis and further developed by Guney, a popular Socratic teacher of TUDelft:

- Take an example that fascinates you;
- Analyse its Form;
- Analyse its Operation;
- Evaluate its Performance;
- Create an Operational structure to reach a better performance;
- Create a Form with this operation;
- Repeat.

This method is known as 'FOP' (Form-Operation-Performance).[b] 'FOP' is strongly based on morphological and structural analysis before evaluation and synthesis. Guney uses the methods of Ching[c], Clark and Pause[d], Steadman[e] and Tzonis[f] at an architectural scale. Burg and Stolk made an excellent overview of methods of analysis at urban scales.[g] Burg, however, experienced the limits of analysis before design in education. My experience is also, that you cannot teach design beginning by analysis. Many studios start by extensive analysis, and the students postpone designing until the last weeks. Asking them afterwards if the analysis had been useful in designing I never received a positive answer. Without making a preliminary design first, you do not know which analysis will be useful to make progress in designing.

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[a] Hertzberger(2002)*Creating space of thought* IN Jong;Voordt, *Ways to study architectural, urban and technical design*(Delft)DUP Science
[b] Moraes Zarzar;Guney(2008) *Understanding Meaningful Environments* (Amsterdam) IOSpress
[c] Ching(1975) *Architecture: form, space, and order* (Hoboken 2007) John Wiley & Sons Inc.
[d] Clark;Pause(1985) *Precedents in architecture* (Wokingham) Van Nostrand Reinhold
[e] Steadman(1989) *Architectural Morphology* (London) Pion Limited,207 Brondesbury Park
f Tzonis(1992) Huts Ships and Bottleracks Design by Analogy for Architects IN Cross;Dorst;Roozenburg, Research in design thinking (Delft) Faculty of Industrial Design Delft University of Technology the Netherlands Proceedings of a workshop meeting
[g] Burg;Stolk(2004) *Urban Analysis Guidebook. Typomorphology* (Delft) Technical University Delft, Faculty of Architecture, Department of Urbanism.

Design education in general

If the teachers of a university faculty do not know in some detail what other teachers teach, then their lectures, exercises and tests may become repetitive. The right sequence of what has to be learned by the students may be lost. I studied the contents of the Bachelors of my own faculty several times in the late nineties, a project that was assigned by the dean. Le Corbusier's Villa Savoye was tested 18 times. The required reading comprised 180 books. I gathered them all at my room physically. I questioned a random sample of students, and determined that most of these books were never read or even known by the students, because the test questions (covering only some pages of the required books) were gathered by the student union and generally known. Lecturers should write down what they want to tell themselves in published lecture papers before they are allowed to give a lecture. It is a necessary exercise for any teacher to obtain the right sequence, to avoid gaps, and to avoid overlaps with the other teachers. Referring to existing books should be additional, the obligation to buy them should be limited, and the pages relevant for the tests should be well-known. The faculty board should steer the content, not the titles of the subjects as they are presented by the teachers if it is not completely clear what they cover. This is particularly important in a design education that integrates many specialisations.

Different titles do not guarantee different contents

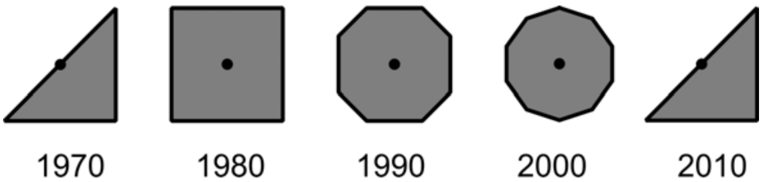
Publishing a new education programme causes a change of titles by the teachers for the same content. The titles are changed to fit in the programme. They may become vague or so general, that they never could be covered by one person. To keep an overview for the students and the board, and to become more precise about the content, the competence of any teacher should be summarised in approximately 50 key words per teacher instead of one title.[a] Duplicate key words should result in meetings between teachers for further differentiation and task division. Key words can be managed by a computer. Students may choose their specialisation based on key words, and even get specified marks for each of them, describing their competence more precisely if they are graduated. They will find their place in the job market in a more appropriate way. But the coordinating power of key words for the board is even more important. It provides them with a direction to develop the education content, determine its appropriate sequence in the educational program, and recognise duplicates and gaps. The gaps may indicate what kind of teachers are missing. The grouping of competencies and the task division between them in a faculty of Architecture as suggested by this thesis is based on three dimensions: the levels of scale in space and time, and the layers of design (see *Fig. 16* on page 52).

[a] A similar inquiry for professors of the faculty of Architecture TUDelft I once did in Jong(1997)*Hoogleraren Bouwkunde InTrefwoorden*(Delft)TUDBk

8.2 Empirical research

A sad history

In the eighties of the last century, the Faculty of Architecture at TU Delft contained three institutions for empirical research, according to three departments of the faculty: architecture, urbanism and housing. The department of Building Technology (closest to the faculties of civil engineering and industrial design) apparently did not require a separate research institution. The employees of the institutions were not designers, and they were often graduates from other universities. The research institutions were removed from the faculty in the nineties because the majority of the design chairs regarded their reports as useless for design. The housing institute survived as a successful separate university institute for government research. Their production had been impressive. For example, their reports on urbanism filled an entirely separate library apart from the main library of the faculty. This library disappeared within a week. I saw its reports and books piled up at the corridor of my building floor. Everybody could take whatever they wished, before they were removed. I rescued some of them for my own library, but this library was burned by the 2008 building fire. The design chairs took over the task of research, but they did not succeed in publishing a comparable quantity of research. They published more beautifully illustrated books than peer-reviewed journal articles. Their subject was predominantly history of architecture and urbanism. The recurring debate on methodology of design related study resulted in many conferences, and finally a book summarising nine types of study and research relevant for spatial design was developed.[a] This book has been used for five years in methodology education, but it has been hardly read by the employees. The department of Real Estate and Housing appeared to be the most successful in publishing. Their economic and managerial orientation on building production and function instead of design fit better with the typical empirical research methods. The pressure to publish in scientific journals and to increase the number of PhD's resulted in a return to typical empirical research. The department of Real Estate and Housing took over the methodology education, and now history is about to repeat itself(see *Fig. 248*).



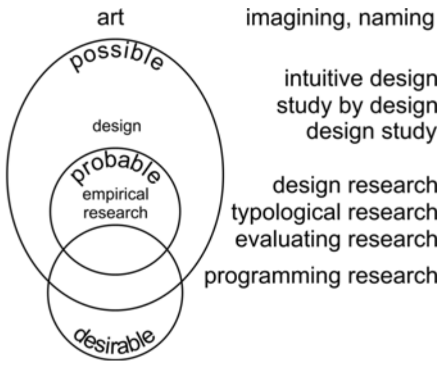


Fig. 248 Methodology of design study and research: the wheel cannot be re-invented frequently enough

Fig. 249 Kinds of study relevant for design

Study and research relevant for spatial design

The specialised probabilities of empirical research seldom convince spatial designers that are searching for possibilities. Sector averages of many cases cannot be integrated as spatial layers in a special case. Separately generalised linear truths from different directions seldom fit a design project's spatial context, or its possible futures that have many dimensions. The parameters that are eventually able to produce a more context-sensitive deviation from the average specialist solution are often hidden in the linear inferences of specialists or their supporting computer programmes. Specialists may even not be aware of

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[a] Jong;Voordt(2002)*Ways to study and research urban, architectural and technical design*(Delft)DUP Science

them; they may assume that they are valid anywhere else or in the future. Moreover, a spatial context often requires many specialists supposing their own, sometimes even mutually contradicting, probabilities. Case studies can be made afterwards to indicate that the assumed parameters are not valid everywhere, but the context-sensitive conclusions of many case studies are even less useful in other contexts than the generalised averages. General conclusions may be useful for industrial designers, who are usually working on less context sensitive mass produced products with a smaller life-span, but not for unique objects in unique contexts. Moreover, design decisions do not concern the functions themselves. They concern the possible forms and structures, the physical *conditions* making the described function (and many other unpredictable and non-describable surprising functions, affordances) *possible*. Written reports cannot sufficiently engage the possibilities of form. The linear character of text is most appropriate to describe separate, one dimensional, probable, straight forward, and causally predictable *functions*. Text is not appropriate to describe two dimensional possible *forms* accomodating these functions. The sideward views of many possible functions, that are so obvious in a drawing, are lost in their causal line of reasoning in texts and calculations. It wrongly avoids logical paradoxes that are *allowed* in drawings. Empirical research has to cope with drawings to become relevant for design. According to Jong;Voordt (2002), *Fig. 249* shows the kinds of empirical research that are relevant for design. I will elaborate on them further along in the text.

Describing and naming

A 4D diversity and technique at different levels of scale considers numerous objects that can be described, typified, and categorised. Compared to the medical nomenclature (facing a similar 4D diversity and technique), the vocabulary of spatial design is very limited. Naming its objects in words may enable empirical science to cope with the diversity of spatial possibilities. For design operations, the *transformation* of an object into a different object is particularly important. Usual language is built up by sentences containing verbs between an actor x and a result y. A complete sentence thus has the form y(x), to be read as 'y as a function (working) of x'.

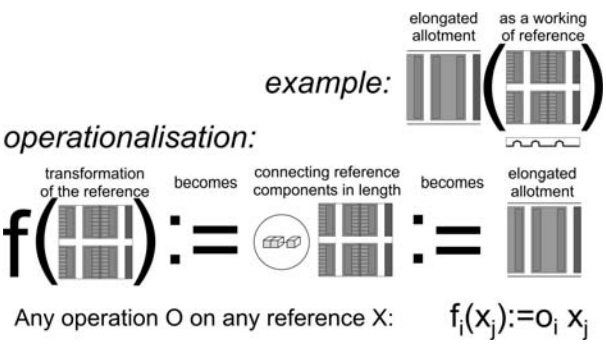

Fig. 250 Design operations

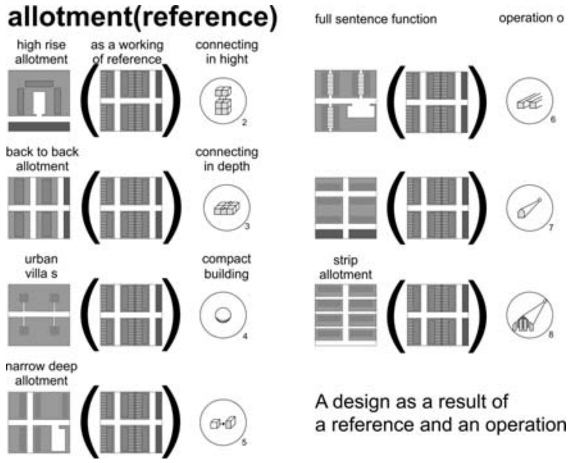

Fig. 251 Results of design operations

The brackets indicate the operation f(x) represented by the verb. In mathematical sentences this operation can be specified, e.g. as $f(x)=x^2$. But design operations concern images instead of numbers. You may replace x and y by images (see *Fig. 250*). *Fig. 251* demonstrates that many obvious design operations still do not have a name. But, if you draw the reference and the result as a complete sentence y(x), then the operation f(x) may be clear enough: 'design(reference)'. This simple notation as 'syntactic key word', however, is useful for many other, more abstract purposes, rather than naming design operations.[a]

[a] See Jong(2002) *Syntactic key words* (Delft) TUD Faculty of Architecture, downloadable from http://team.bk.tudelft.nl/Publications/2002/Syntactic%20keywords.htm

If I read villa(landscape) as ‘A villa as it is influenced by (as a function of) a landscape’, then it may be the shortest formula for a study proposal. Landscape(villa) would mean a different study proposal. The ‘working’ to be studied (the verb) is replaced by brackets ( ). A complete sentence y(x) does not have to *specify* its operation. That is an advantage, if you want to study or research an unknown operation. Research always aims to know ‘how it works’; design study aims to know ‘how it *can* work’. In both cases, the working is not known beforehand, and that is precisely what a complete sentence expresses. If the operation is still undetermined, then it can be interpreted as any operation:

- intuitive: f(x):= y associated with x;
- conditional: f(x):= y possible by x;
- set-theoretical: f(x):= y part of x, encloses x, without x ...;
- logical: f(x):= y if x, not x ...;
- mathematical: f(x):= x+x , x^2...;
- causal f(x):= y caused by x;
- temporal: f(x):= y preceded, followed by x;
- spatial(formal): f(x):= y near to, contiguous to, surrounded by x;
- structural: f(x):= y connected with x, separated from x;
- combinatorial: f(boards, nails):= a combination of boards and nails (e.g. a box).

A further advantage is, that this notation allows ‘nesting’ to become more precise. A verbal sentence cannot easily express more extended nested operations. For example, villa(landscape) elaborated in a ‘nested’ form produces different objects of study:

- villa(landscape(water-system))
- villa(landscape(water-system,history))
- villa(landscape(water-system(history)))
- villa(landscape((water-system,occupation)(history,spatial dispersion)))

If ‘)(‘ appears in the formula, then it may suggest a list of contents for your report:

1. water-system(history)
2. water-system(spatial dispersion)
3. occupation(history)
4. occupation(spatial dispersion)

The object of study does not have to be as concrete as a villa or a landscape.
It may be more abstract:

- urbanity(liveliness, choice)
- urbanity(liveliness, choice)(density, variety)
- form(function)
- function(form)

If the object of study contains opposite design methods such as ‘form follows function’ and ‘function follows form’, then you need the two last sentences both. If the sentence becomes to long to be understandable, then you can easily split up the sentence in more sentences. The object of study of this thesis could be summarised as:

- environment(diversity(design))
- design(intention(function(structure(form(content(scale,direction))))))

Combining them would not fit one rule. The index of this thesis (see page 322) uses short, complete sentences as syntactic key words, in order to allow you to find the precise subjects you are searching for more easily. It enables you to follow the range of words that successively define a concept, such as ‘design’, in this thesis. If you take x and y as environmental *variables* (see *Fig. 74* on page 114) then complete sentences may cover a diversity of *possibilities*. E.g.: $\text{Articulation}_{30m}(\text{Altitude}_{100km})$, or more precisely: $\text{Articulation}_{30m}$(horizontal … vertical)($\text{Altitude}_{100km}$(lowland … highland)). It could produce a sequence of chapters:

1. horizontal articulation of building groups in lowlands
2. vertical articulation of building groups in lowlands
3. horizontal articulation of building groups in highlands
4. vertical articulation of building groups in highlands

But, a variable may concern many values in between two extremes. They are better represented as points in an x-y graph, than in a linear text, divided in chapters. And, *Fig. 74* on page 114 contains many related variables. Any relation between two variables, any combination of two of their values, still may have an infinite number of possibilities in regards to how they are dispersed in space. ‘Form’ thus is a second-order variable that is superimposed on the primary environmental variable. And, this thesis suggests that any form can be realised with different structures, producing a third-order variable of structure. Then, there are still fourth and fifth order variables of function and intention. All of these orders require design decisions. Could they be supported by empirical research? Naming design-relevant variables unveils at least the vast area of undiscovered design-relevant empirical research.

Design research and typology

Design research is studying examples (references, precedents) of different scales, their content, form, structure, function, and intention as inward operations and outward performances at different levels of scale, in different time spans, and from different (managerial, cultural, economic, technical, ecological and spatial) viewpoints. A design research programme should start distinguishing the design relevant variables according to space, time and layers as shown in *Fig. 16* on page 52:

(R=0.3m … 30km)(days…centuries)(layers).

According to the classification of that scheme, there would be at least 180 objects of study possible for each example. If you distribute these objects of study over the disciplines of *Fig. 16*, then there would be 180 disciplines involved, communicating in 180 specialist languages. And, there are many examples that should be studied before you may, or may not, arrive at a typology (see page 270) that is useful for any design. It is obvious, that such an endeavour is a hopeless task. But, it puts any case study in perspective. It makes the object of study nameable and retrievable by key words, representing a set of limited variables. The case studies I know could be characterised that way:

- Example(space, culture)(centuries)(R=30m)
- Example(space, technology, culture)(centuries)(R=300m)
- Example(space, technology, economy)(months)(R=1m)

This characterisation, however, only concerns the variables involved, and the content. But, what about the form, the structure, the function and intention? For empirical research, they are implicitly included as variables in the physical and social layers. In this thesis, they are made explicit for design, which can be considered the art of improbable possibilities. For empirical research, only existent examples are relevant, not the possibilities to change them otherwise than proven in other existent examples. The existent form may play a role primarily in space (the actual form) and culture (the perception of form); the existent structure may play a role in ecology and technology. The primary object of empirical research is the existing object and how it works in the layers of an existent context, not the making of an object that still does not exist (see *Fig. 50* on page 93).

Evaluative research

Evaluative research is a kind of design research that explicitly takes the mode of desirability into account (see *Fig. 249* on page 273). It occurs frequently in nearly any design process of an object in progress, or after realisation, in order to prepare programming studies for similar projects. Any specialist evaluating a drawing as a manager, a client, an economist, a technician or an ecologist, evaluates if the impacts are desirable in her or his domain (see *Fig. 234* on page 256). Any specialisation has its own methods. This thesis does not discredit them as truth-finding. It puts them in a perspective of possibility-finding. This may have some consequences as already has been explained in Chapter 7 in pages 245 and onwards.[a]

Programming research

Making a brief surpasses the boundary of probability, by studying non-probable desirable futures (see *Fig. 249* on page 273) within the limits of what is supposed to be possible (see also *Fig. 2* on page 17). It translates intentions into functions, which are mainly based on a limited imagination of existing types and examples. Programming research is inclined to extrapolate probabilities into desired possibilities. But, if the client is a less experienced institution or person, then the brief may be made in interaction with a designer. The designer will introduce possibilities that are beyond the client's existing desires. In that case, you could name this kind of research 'programming *study*'. If many stakeholders and specialists formulate their desires, then 'optimising research' is part of the study. Both are elaborated on often enough, so it is not needed to elaborate further on them in this text.

[a] See also the Chapter 'Evaluating' in Jong;Voordt(2002) *Ways to study urban, architectural and technical design* (Delft) DUP-Science http://team.bk.tudelft.nl/Publications/2002/Jong(2002)WaysToStudy(Delft).pdf

8.3 Design related studies

Technical study

Technical study in a design environment goes beyond ‘construction’. It has consequences for more encompassing design study. It is a means-directed exploration of mere technical *possibilities*. *Desirable* futures play a lesser role. Technical inventions have changed people’s desires, their economic demand, their culture, their priorities. Existing desires are based on what people know, and what they *suppose* to be possible. A good example is the invention of how to use computerised fabrication in order to produce curved glass surfaces that fit in curved façades.[a] Nobody wanted them before their possibility had been proven and the suppositions about their price had been falsified. Once this had happened, it became a hype in order to fulfill hidden desires of identity and representation through surprising buildings. Short term valorisation may hamper technical study. Its risks may by high, but trusting the limited imagination of the majority of people leads to a technological stand-still. Technical study has its value, even if the result may be, that a construction is not possible or too expensive in the given circumstances. Reporting the failure of an idea in detail may be not very popular, but it is essential in the advancement of technology. I have learned more from failures in construction than from the many advices how to construct ‘properly’ according to the existing experience. The physical technical experiment is a crucial part of technical study. Its sup-posed operation is the ‘hypo-thesis’ to be tested by empirical research. The method of empirical research may be rather strict, but the choice of a hypothesis to be tested is fundamentally free. If the hypothesis is not free, then you may realise the consequences if you remind the history of Copernicus and Galilei. If the choice of an *experiment* is not free, then you will miss the possibilities that may be opened up by the experiment. In technical study, the hypothesis requires the greatest effort. The testing is the minor part of the study. The hypothesis contains an often expensive operational structure to be built first, *before* you can test its operation in an empirical way. Its eventual failure must be reported in detail before you may find (often minor) successful improvements. The role of experiments and thought-experiments will be elaborated further in the paragraphs below.

Design study

Design study is the usual activity of design bureaus with projects in determined contexts (see *Fig. 50* on page 93). It is a possibility-search that is limited by the many probabilities and desires stemming from this context, its specialists and stakeholders. But, the imagination of these probabilities and desires are often bound to a shorter term than the object of design will exist. The designer may increase the flexibility of imagination of the stakeholders and specialists involved, by showing possibilities and discussing the future context (see 7.4 on page 253). Design study does not solve single problems. It must cope with a field of related problems and aims stemming from more than one specialist or stakeholder. The role of experiments in design study is limited. The scale models made to imaginate a 3D design proposal do not include people. As it is the case in the humanities, you cannot experiment with people bringing them into the extreme situations as technological study may do with dead materials. Experiments of design study beforehand, are mainly thought-experiments *supposing* human behaviour in the unprecedented context proposed. The final experiment is the realisation of the design. Its eventual failure is seldom an object of evaluative research. It may harm reputations and it may decrease the value of the object. The owner will object its eventually negative conclusions in order to provide for its yield. The lacking support for evaluative research reduces the progress in design study to the application of technical advancements. It may be the task of universities. As Hertzberger advised his students to extend their imagination through putting existing examples in a different context (see page 271), taking existing *contexts* not too serious adds new possibilities for design study. This is meant by ‘study by design’.

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[a] Vollers(2001) *Twist & Built creating nonorthogonal architecture* (Rotterdam) 010 Publishers

Study by design

From a viewpoint of empirical research, study without a determined object and context (see *Fig. 50* on page 93) is bizarre. It cannot formulate a clear problem or aim, and its outcome is uncertain. It may come closest to visual Art. If it is Art's task to explore what is *imaginable*, then the task of study by design is to explore what is *possible* within that area of the imaginable. For example, Escher's work is imaginable, but not always possible. The field of study by design is consequently smaller than that of Art. It studies possibilities by means of executable design. Study by design, then, is not primarily aim-directed, but means-directed. This thesis studies these means of design in order to extend them into the boundaries of what is imaginably possible. The means of design distinguished in this thesis are its orders of diversity: content, form and structure at different levels of scale, in different contexts. Technical design is restricted to structure, but design study does not have to start there. Design study has not one method in the sense of one particular sequence to be followed, but it can be done systematically. It can choose to experiment with different forms that are possible with one particular structure, but it can also start with one particular form to explore which structures are possible to realise that form. It can be cyclic, adapting the structure in order to reach even more improbable forms and then adapt these forms to reach even more improbable structures. It that sense, it serves design studies without the burden of a particular context. Form and structure are well-known means of design, but they suppose a third order: content, the values that are taking form and structure, the legend units in a drawing. They are often forgotten through the supposition that they are limited, but they are not. They are neglected with the consequence that they have become limited by tradition, a lack of awareness of their possibility to diversify environments. Technical study did not forget content, because any construction requires well-defined materials. The great advancements of technology even started often through emperiments with matierials. Materials in the sense of content that can take form and structure, do not only contain wood, brick, concrete, steel or glass. Its study goes beyond building materials. It encompasses any chemical substance applicable at different levels of scale. In fine mechanics diamond and gold are studied to determine which forms they can take, which operations are possible at the lowest levels of scale, even regardless which function these operations may possibly perform. Experiments forcing materials in extreme and very improbable conditions are the core of this kind of study. Content, however, is not only limited by chemical substances. For example electricity is also a kind of content that may take different forms, that can be forced in different conditions and structures by experiments. It has been discovered in the 18th century. Many experiments have been done without any prospect on substantial application, before the applications we know now, had been realised. This thesis started with an inventory of contents that can take form at larger levels of scale than electrons and molecules. If it succeeded to extend the awareness of the values you can imagine in the diversity of environments (the legend units you can use in your drawings at different levels of scale), then there is a long road of experiments ahead. They can be done without any prospect on substantial application, but it would be improbable if there would never appear any application that may change the world. The ordinal arrangement of values in variables may be a tradition that is typical for empirical science, but in the two or three dimensions of a drawing, different values (legend units) may be exposed to each other in a combinatoric explosion of arragements opening up new possibilities. It is the task of study by design to explore these possibilities systematically through thought experiments. Take a variable and distinguish as much values you can. Look which dispersions in space (forms) are possible for every value as a legend unit, look how you can combine them with other values of other variables, how you can stabilise the form by some structure, still regardless of the functions in can perform, the intentions it can fulfill. This context may hamper the possibilities of design. Designers with a sufficient luggage of possible contents, forms and structures may be ready to accept assignments for design study.