9 Conclusion

A linear language cannot cover space, its diversity or possibilities

Words collect earlier experiences as sets, neglecting the differences between their elements. They reduce reality into a 'linguistic average'. Sentences, then, connect averaged nouns with averaged operators, (i.e. verbs or signs referring to generalised actions) in a strict sequence. A sentence cannot be read backward, not to mention sideways, unlike a drawing. This thesis tends to be an affirmative answer to Jackson's question: 'Is it possible that we … are unconscious victims of our language when we attempt to interpret architecture?'.[a] Every brick, beam or plate is a part of many sequences, in many directions. A linear language cannot tell the many possible stories of every element. It reduces reality into one 'linguistic direction'. The language of speaking, writing and calculating is primarily time-based. It reconstructs a reality through imaginary operations. Describing space in a line of words in one direction (i.e. the arrow of time), however, cannot be more than a travel report that neglects the side roads, and the more remote context. Moreover, it substantially reduces the spatial diversity (as it has appeared to your senses) into commonly generalised words. Crossing lines may indicate points, and their mutual distance is represented in words. But, Cartesian points and distances cannot describe the experience or use of the space. In other words, they even substantially reduce the *awareness* of a possible diversity. A thesis is assumed to be expressed primarily in words, propositions or calculations, but this thesis meets their limits.

[a] Jackson(1994) *A Sense of place, a sense of time* (London) Yale University Press p32

Poetic associations cross the line, but design covers many more directions

Using words as descriptions requires to assume that these descriptions will lead the audience or the reader to recall similar experiences, but you cannot be sure that they will do so. Words act in a 'linguistic game', a context that hides many suppositions (i.e. a '(sub)culture': a set of shared suppositions enabling communication). The linguistic game of poetry may evoke different imaginations by unexpected combinations of words. It may reset your imagination or extend it into different directions, but it will still not cover the possibilities of space a designer must balance. It allows to re-arrange the sequences of reality by imagination, but it is still bound to the sequence of words in a sentence. You may fill the words of a poet with the experiences you may recall yourself: smells, sounds, emotions and places you vaguely remember, combining them in unexpected sequences, but future-oriented spatial design must be more. Poetry is closely related to the other time-based art of music, evoking the same kind of recollections. Their combination in a song, however, seldom reaches a sublime unity of sound and story on their own. The appearance of video clips adds a spatial dimension covering the eventual poorness of one of both mixed in a synaesthetic experience as operas and musicals did before. Dance then adds a substantial and fascinating motoric sensation in order to experience touch and space. It puts story and sound into perspective. This is the spatial perspective of closeness and distance supposed in any sequence.

The direction of linear reasoning cannot be determined by linear reasoning

Even the *choice* of the direction or route, its beginning and its end, as applied in this thesis, cannot be justified in sentences with only one direction. A picture or a map may help, but it also does not fully show the context and tacit[a] (but not less valid) arguments of such a choice. You cannot describe all the side roads that you passed by in words, except by referring to footnotes, other reports or chapters. If you would describe all side roads this way, your listeners or readers would lose the 'thread' of your inference. They would reproach you as 'deviating from the subject'. They like the connecting word 'thus' more than the separating 'but'. Your report, thus, may result at most in a tree-like structure, with one stem, and separate chapters describing some branches. In the common language-games of policy, management, empirical science and the humanities, a line-wise reasoning is useful and broadly accepted. Spatial design and technology, however, require more dimensions than the one provided by common linear language. The pictures of this thesis are thus not clarifying the text. Rather, the text clarifies the pictures, by taking seemingly arbitrarily chosen routes in their still two-dimensional space. The references in the text mainly refer to figure numbers instead of chapters, sections or paragraphs. This is not accidental.

Space includes the gaps between the linguistic lines of reasoning

This thesis, in regards to diversifying environments through design, cannot avoid taking on a tree-like structure that is full of gaps, which are left to be filled by the imagination of the reader. It attempts to grasp the sky by a stem (i.e. the describable diversity of environments) branching into variables. Variables are words, each assume a sequence-bound line of values. These lines crisscross the air, without any possibility to offer a complete coverage of the sky, but they have the capacity of further branching through space. The reader must jump from one line into the other, in order to experience the gaps and to discover the *possibilities* of space. The conceptual tree and its branches can be cut into pieces, in order to obtain a different form and structure, and to fulfil a different function and intention. The values of the variables can obtain different sequences in space, compared to the sequence you needed to imagine them in their simple linguistic line-form. A second branching (i.e. a second order of diversity) opens up another universe of possibilities for every single variable or value: the inconceivable possibilities of form. The kind of linear logic reasoning (valid for relating sequenced variables) must be left behind. This is not an easy transition of

[a] Polanyi(1966) *The tacit dimension* (New York) Doubleday

reasoning. The transfer into the second order of 'branching the branches' requires a different kind of thinking in forms, allowing contradictions that are perpendicular to the primary line of reasoning.[a] A bridge is open *and* closed. A boundary, a road or a pipe line connects *and* separates, depending on the tacit direction of reasoning. Which kind of reason can cope with such contradictions? Does every branching grafted on branches of a previous order have something in common? Is 'form' the final order of branching? This thesis cannot answer these questions in a sense of 'truth'. It only shows some 'how'-answers, proving their 'possibility'. Focusing on possibility raised the many methodological issues addressed in Chapter 1 and 2. Some possibilities to overcome these barriers, however, are demonstrated in Chapters 3 - 8. Until now, this Chapter has drawn some conclusions concerning these barriers. The rest, thus, primarily concerns chapters 3 - 8.

Superimposing 'form' multiplies the possibilities of 'content'

Diversifying an environment primarily assumes a possible *content* of its diversity. This content can be described in the one dimension of common language, by naming variables and their sequenced values. Interpolating and extrapolating these variables can extend the observed diversity into new, possible values. These values can be used as legend units in a drawing, but there, they may lose their original position in the verbal or mathematical sequence of the variable. This increases the number of possible sequences in space. The values of different variables will show different sequences in different directions. This combinatoric explosion of potential forms is superimposed on the potential content. The dispersion of a legend unit in space (i.e. its 'form'), and the possible diversity of this second order, cannot be described fully in common linear language. It requires at least two dimensions. Form can be imagined without a determined content, but it tacitly supposes *some* content (e.g. the black and white of a sketch). Describing structure, however, requires imagining simultaneously at least three dimensions, function 4D, and intention even 5D. Function adds time as a necessary explicit dimension to the three dimensions of structure, and intention subsequently adds a dimension of desire. An intention, however, concerns *some* function to be desired, and a function tacitly implies *some* structure within which it can function. A structure (in this thesis defined as a 'set of connections and separations') subsequently requires *some* dispersion in space of *what* is connected or separated (i.e. *some* content), even if this 'form' is still topologically variable.

Super-position supposes sub-position in a conditional sequence

Thus, the successively distinguished and superimposed diversities of content, form, structure, function and intention also obtain a sequence that is represented in the chapters of this thesis, but it is not a causal sequence of operations. It is a non-logical 'conditional' sequence, producing possibilities instead of probabilities. The variation of some variable does not make the dispersion of its values in space *probable*, it makes still different forms *possible*. It is not a preferred sequence in a design process, either. A design process may begin anywhere, imagining an intention, a function, a structure, a form or a kind of content, but once you have determined one, the other conditions must be determined in order to realise it in this sequence, proving its possibility.

The meaning of words can change by scale

Text-based literature can draw unreliable conclusions if the scales within which they are valid are not explicit. The content (i.e. the 'material', the set of variables describing the design-relevant possible diversity of environments) is bound to scale. Many variables have an upper and lower limit of resolution (this thesis refers to them as 'frame' and 'grain'). Changing the resolution may substantially change the meaning of the variable. For example, the environmental variable 'light', varying in a radius of 1 metre, distinguishes environments

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[a] This 'thinking sideward' is perhaps related to the 'lateral thinking' intended by Bono(1967) *The Use of Lateral Thinking* (London) Jonathan Cape or Marcuse(1964) *One Dimensional Man - Studies in the Ideology of Advanced Industrial Society* (Boston) Beacon Press

differently from the way it does in a radius of 100km. The question of how to determine the limits of scale, where one meaning changes into a substantially different meaning, has been answered in my first thesis[a]. But, this answer was given a better foundation in this thesis. *Fig. 7* on page 21 and *Fig. 17* on page 52 show their foundation: the scale paradox and the concept of a 'nominal radius'. *Fig. 7* proves that already a factor three difference in a 2D scope can cause opposite conclusions about 'difference' (scale paradox). This suggests a logarithmic sequence of orders of size, in order to determine where a variable may obtain a different meaning, but it still does not determine the limits themselves. For many practical reasons, (the size of built-up areas[b], the mesh-width of networks[c], measures easy to remember) the semi-logarithmic range {… 3, 10, 30m …) has been applied in this thesis. These measures, however, are still too precise to distinguish environments of different 'orders of size'. *Fig. 17* thus shows in which range they can be interpreted, if you give them a broader 'nominal' meaning. A *nominal* measure of '10m' ,then, can be interpreted as any size between 3 and 30m. This flexibility may cause overlaps, but in this thesis it has appeared useful to distinguish orders of size of content, form, structure, function and even intention. In order to make these orders of size independent from directions, I chose the *radius* of the circular frame R and the grain r, in order to indicate the *nominal* size and resolution r/R. You now can use a nominal radius R to indicate an order of size, and add r to determine the intended resolution r/R. A sketch, then, has a resolution r/R of 1/10, a drawing of 1/100 and a blueprint of 1/1000, with very broad margins. Any picture between r/R = 0,3/300 and r/R = 3/30 may be named a 'drawing'.

The concept of 'form' as 'distribution in space' has nameable extremes

In this thesis, the concept of 'form' is separated from suppositions of 'meaning'[d] and coherence, or even adjacency, between elements. 'Meaning' is assumed to be a possible *function* of a form for humans, but the form itself is limited to 'distribution (of some content) in space'. Coherence is assumed to be the effect of a possible *structure* of form. A set of connections and separations stabilise the form, giving it coherence. The same form may have different structures, (i.e. a third order of branching in the thesis) and the same structure may have different functions (i.e. a fourth order of branching). Even the adjacency of the elements that give the 'form' a clear boundary (i.e. 'shape') is not necessary to ex*plain* 'form'. Without a supposition of adjacency, you are able to think about the 'form' of some dispersed content (e.g. trees, parking lots, buildings). The 'form' of a city depends on the distribution of built-up area, but between the buildings, there are still many public and private open spaces that represent other values than 'built-up'. If the city-outskirts gradually turn from 'built-up' area into open rural land, the boundary cannot be unambiguously determined. If you skip the connotation of boundaries and adjacency of its content, then any separate value can obtain a describable form between extremes of total accumulation and total dispersion, at any level of scale. This seems to open up the possibility to describe 'form' as a variable between these extremes. A line, then, would be the total accumulation in one direction, and total dispersion perpendicular to this direction. Total accumulation can be described as the absolute value or zero-point from where the deviations can be measured. This, however, does not solve the question of how to measure deviations from these extremes (e.g. local thickenings of the line or accidental surfaces outside the line) in different directions. This thesis did not succeed to cover the possibilities of form in a systematic way. The number of forms between the univocal extremes shows a combinatoric explosion of possibilities, which cannot be solved by two or three extremely different (perpendicular)

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[a] Jong(1978) *Milieudifferentiatie* (Den Haag) RPD TUD

[b] For example, Blaeu(1652) *Toonneel der Steden* (Amsterdam) Blaeu, shows mainly cities R=300m, a size now known as 'neigbourhood'.

[c] Nes;Zijpp(2000) *Scale-factor 3 for hierarchical road networks a natural phenomenon?* (Delft) Trail Research school

[d] Forty(2000) *Words and Buildings A Vocabulary of Modern Architecture* (London) Thames & Hudson p149 writes: "There is in 'form' an inherent ambiguity between its meaning, shape' on the one hand, and on the other 'idea' or 'essence': one describes the property of things as they are known to the senses, the other as they are known to the mind." The last connotation of a platonic $\varepsilon\iota\delta o\sigma$ (appearance *and* idea) is thus rejected in this thesis.

directions (Cartesian coordinates). A reduction of the inconceivable number of possible forms, however, can be reached by distinguishing between different *resolutions* or levels of *scale*.

Different resolutions produce different forms

If 'form' is a human construction derived from what you can observe through your senses, then it is limited by their resolution. The form of a building is different from the form of a city. Changing the frame of a photograph changes the forms or compositions you perceive. The often invisible structures that stabilise these forms at different levels of scale are different, and for every particular form, there are still many structural and functional alternatives. Thus, studying form at different levels of scale separately simplifies the study of form and its consequences substantially. Forms at different levels of scale, however, are mutually related. The topography and geomorphology of a land limits the remaining possibilities of urban and agricultural forms. It seems reasonable to assume that the larger form mainly sets the boundary conditions for the smaller form, but there are many examples of smaller forms determining larger forms (e.g. by repetition, the growth of crystals, a design composition). Therefore, this thesis does not suppose a conditional sequence of scales. Looking at the diversity of forms from $R = 10^{-18}$ until $R = 10^{26}$m, the greatest diversity seems to appear between $R = 10^{-6}$ and $R = 10^{6}$m.[a] The diversity of forms at the lower scales increases from physics into chemistry, and from chemistry into biology. The diversity of forms at the larger scales, including the diversity of human artefacts, does not measure up to the inconceivable diversity of organic forms, until 1m. At the even larger scales, the diversity of forms decreases. The development of the organic form within and outside the living cell (R = 3 - 30μm) is increasingly limited by structures that develop as stabilising parts of the form. Separations and connections increasingly limit the degrees of freedom of its elements (their entropy). In the human design of artefacts, forms can be imagined (not realised) without structure. This enables the imagining of alternatives of structure that can stabilise the same form. In 'evolutionary design', however, the form results from gradually adding structure (imagined as 'rules' limiting movement and change).

The most general structure is a polarity between 'closed' and 'open'

A connection limits movements into one direction, through separation into other directions (see Fig. *Fig. 130* and *Fig. 131* on page 185). You cannot connect your lamp with the electricity grid without isolating the cables. Separation is a necessary condition for connection. In other words, connection *supposes* separation, not the other way around. Space operates as a primary kind of separation. Its degree of separation can be expressed as distance. A zero-distance between two objects may be called 'connection', but it limits the movement of one of the objects to only one direction. The other directions are still 'open' for movement, but other objects at some distance into the other directions still limit the freedom of movement. Therefore, following the inference above, instead of referring to 'openness', you may better refer to a 'low degree of seclusion'. The development of organic form very often shows successive degrees of seclusion. If they are ordered in a sequence from closed to open, there is a structural polarity between relatively 'closed' and 'open'. This polarity can be recognised in the development of organs, organisms and organisations.[b] It probably allows different degrees of freedom from regulation into coincidence and entropy. This polarity also can be recognised in utensils, furniture, buildings and cities. This thesis proves the possibility of the application of polarity at any design-relevant level of scale. Studying the possibilities of subsequent levels of scale suggests an alternating appearance of motoric and sensoric polarities at every factor 3 scale difference, according to the scale paradox.

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[a] See Boeke(1957) *Cosmic View* (New York) John Day, and Morrison;Morrison; Eames;Eames(1982) *The powers of ten* (New York) Scientific American Books, Inc.

[b] Sinnott(1963) *The problem of organic form* (New Haven) Yale University Press

Spatial functions cannot be designed

A designer may take a list of desired functions (e.g. a brief) as a starting point for design, but fulfilling these functions is up to the users after the design is realised. As a designer, you cannot do more than afford *possibilities* of use. You do not design a house to *cause* a predictable household, you shape *conditions* to make many households *possible*. You must propose a content, a form and a structure first, before they can be evaluated on the *probable* functioning of your design by stakeholders and specialists (i.e. evaluating research). The larger the object of design, the longer it may be used, the more people of next generations will use it, the less certain will be its uses and the more adaptable or multi-functional it must be. Smaller mobile objects of industrial design, with a shorter period of expected use, can be designed for specific functions that fulfil the desires of current generations in many contexts. These desires can be predicted by empirical research, and fulfilled by mass-production. But, larger location-bound objects with a longer time-span of existence have different functions in a *specific* context. What *can* be studied concerning their functions *in general* (i.e. at average) has diminishing returns, because every environment is unique in its potential. What *can* be generalised for any environment is already generalised many times by empirical research.[a] What remains to be studied are *specific* cases, their relevant spatial, ecological, technical, economic, cultural and managerial *layers* of context, at different *levels* of scale in space and time, represented by different stakeholders with different expectations. Their expectations and desires, affected by an object still to be designed, stem from their *position* in different layers and levels. Before summarising their desires, a designer may first locate their positions, and make an inventory of *expectations* from each position. This may produce more generally expected futures in a determined time span. These *probable* futures determine what is *not* desirable (i.e. the 'problem *field*'). This strategy avoids thinking in a linear linguistic average of desired functions, neglecting the broader possibilities of design. It provides a *field* of aims.

Mono-functional environments postpone satisfaction

A spatial design is thus functionally layered, and more or less multi-functional. The traditional home or autarkic farm is the most multi-functional R = 30m environment from which the history of specialisation separated mono-functions (e.g. work, education, care, religion, recreation) into a larger urban area.[b] It still enables a spontaneous choice of immediately satisfying (solo-functional) actions. It compensates the forced sequence of not immediately satisfying (inter-functional) actions of a programmed working week outside, where the agenda rules. The necessary sequence of inter-functional actions to reach a final satisfaction has been extended by involvement in the aims of your employer or client. In the course of human evolution, task division has increased the number of inter-functional actions in mono-functional environments, at the cost of solo-functional actions in multi-functional environments. Urban design may develop more multi-functionality R = {100, 300 and 1000m} in order to restore more solo-functional actions.[c]

Any object with a useful interior has at least two functions

In this thesis, and thus tacitly in the previous paragraph, the concept of 'function' is limited to functions for (wo)man and society. Even with this restriction, however, the concept of function is ambiguous. A house may have an outward function for the city (and its inhabitants), but it also has a different inward function for its occupants. The difference between inward and outward function is often neglected. It is based on two opposite directions of view, sometimes leading to contradictions. For example, a house *affords* space for its occupants, but it *takes* space from the city. The sensory perception of a building outwards and inwards is substantially different. If you diversify the outward function into more directions, then there are even more functions to be distinguished. Your house may

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[a] For example Neufert(2001) *Architects' Data* (Malden, MA.) Blackwell
[b] Mayntz(1955) *Die moderne Familie* (Stuttgart) Ferdinand Enke Verlag
[c] Hoog(2012) De Hollandse Metropool, ontwerpen aan de kwaliteit van interactiemilieus (Bussum) Toth

have different functions for your right, left, and rear neighbour, and for the street. The same may apply for the inward functions. A sentence, such as 'This house has a positive effect upon its neighbourhood', hides many functions in the 'linguistic average' of its statement. Moreover, this effect or function should be distinguished further, into levels of scale and layers of context. Do you mean a spatial, ecological, technical, economic, cultural or managerial effect (function), or an overall effect with an implicit evaluation and balancing of its components? Does it apply for the direct neighbourhood R = 100m, or for a wider neighbourhood R = 1000m?

A design affords more functions than ever can be summarised in a brief

Any list of desired functions for a spatial design or brief falls short of what humans need. In its time span of existence, a realised spatial design may obtain numerous unexpected 'tacit functions'. Desires will change at different levels of scale, and in different layers of context. A periodic change of politics will alternate between priorities for the higher and the lower levels of scale. New stakeholders will appear with new spatial, ecological, technical, economic, cultural or managerial priorities or innovations. A natural response of design to these uncertainties is providing diversity at different levels of scale in the spatial layer, inspired by the diversity in the other layers of context. The uncertainties concern the current and future intentions that are assumed to be directed by free will. This possible variety beyond the brief justifies a backward effect on the design, and on the imagination of the designer. (S)he must extend the imagination of the current stakeholders and specialists, through design from their probable and currently desirable futures into *possible* futures. The aim is to realise a design that *extends* human possibilities, instead of *limiting* them through mono-functionality. The diversity of intentions is not merely a barrier to finding a clear linear route from the problem to the aim. But, it is also an opportunity and a challenge to diversify environments in different directions, solving *many* problems, and fulfilling *many* aims in space. Space enables many routes instead of one.

Space allows realisation of contradictory intentions

The great advantage of space is its capability to allow contradictions to be next to each other (e.g. dark *and* light, wet *and* dry, cold *and* warm). Freedom to choose between them primarily requires separations. *Separations* maintain *differences*, enabling selective connections (e.g. windows, staircases, doors, roads, lines of vision and motion), which can be referred to as 'selectors'. Selectors based on separating environments have made life possible, from its smallest until its largest scale. In the living cell, membranes create separate environments for different chemical processes in order to regulate their sequence. Cells are separated from the outside world by a different membrane, and so are organs, organisms, organisations and landscapes. They are separated from the rest, in order to obtain their own identity. Non-selective *connections* produce *equality* rather than difference. Space primarily separates, but it allows connection at the cost of time. Contemporary society emphasises connection and exchange. It neglects the necessary differences, in order to make exchanges valuable. Exchanging the same objects has no use. Separation sounds negative, but separations are necessary to enable a valuable, selective connection. You are, however, educated to think in connections. Your linear language emphasises the *connections* in an argument, but without sufficient *difference* between the words, the argument becomes meaningless.

Knowledge is a set of tested suppositions

Suppositions[a] may give direction to your actions, but they may also hamper them. The core of education, study and research is to transfer and to create more useful suppositions than those that are usually taken as a basis for action. People act with different and mainly unconscious suppositions. If you build your argument upon tacit suppositions[b] that you do not share with your audience, then this causes failing communication and education. Therefore, any inference or course requires an awareness of suppositions in order to obtain the right sequence. Any spoken or written language contains an extended set of common suppositions. Every spoken or written word implies the dubious supposition that it refers to similar past experiences. Their similarities are named in words, recalling a constructed 'average experience'. Without any memory of experiences, you cannot name their supposed similarities in words, and their connection in sentences remains meaningless. The supposition that there are similarities in different experiences is dubious, *because* they are different. The similarities have proven to be useful in giving direction to one's actions in similar situations, but the situation is never exactly the same. The direction of human action is linear and primarily time-based. The necessity to communicate *actions* may have been the prehistoric origin of language. Words are the shadows of action.[c] Any action can be described by a verb referring to similar actions in the past. It connects the initiator (the causing *subject*) with its effect (the affected *object*) in a complete sentence. The situation of action, however, has more dimensions.

Design education, study and research goes beyond the limits of language

Space is experienced visually primarily via a two-dimensional impression on your retina.[d] The third dimension must be constructed (i.e. imagined) by movements that are perpendicular to this planar scene.[e] The visual impression is continuously replaced in a flow of parallel images, fading in a series of memories connected through your own actions of movement. A spoken or written linear language is well suited to describe these *actions*. The *situations* with at least two dimensions and a spatially constructed third one, however, must be averaged to be named in generalising words (e.g. 'at home', 'in my office' or 'in the forest') in order to fit into a linear sentence. These situational indications are in addition to the sequence of your sentence describing what you have experienced through the actions of

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[a] 'Supposition' stems from Latin: sub-positum (placed underneath). It is exactly the same word as Greek υπο–θεσισ (hypo-thesis). In this thesis anywhere possible the word 'knowledge' is avoided, because it assumes a 'truth-value'; it does not allow a 'possibility value'. Instead, 'knowledge' is replaced by 'set of tested suppositions' as it is always open for falsification and improvement. The 'truth' value of a statement is thus only temporarily. There is fundamentally no 'knowledge' or 'truth value' concerning *possible* futures. Instead, there is a 'possibility' value. From this viewpoint, the term 'design knowledge' is misleading, but 'design suppositions' can be applied to possible futures indeed. Suppositions are imagined reconstructions or simulations of an assumed reality 'standing outside' of you (Latin ex-statum, recognisable as ex-sistent or existent). The 'possibility' of a supposition can be tested by realisation, a series of actions based on these simulations. Your actions follow a simulation, directing your muscles by a motoric nerveous system. In this sense, suppositions give direction to your actions.

[b] Suppositions suppose other suppositions (e.g. 'Suppose p, then q is true or q is possible'). The search for suppositions 'placed underneath' a given supposition, however, does not primarily require a logical or causal 'if…then' test (producing a truth-value or a probability-value). It primarily requires a conditional test producing a 'possibility-value' (*including* truth and probability see *Fig. 2* on page 17). The logical propositions 'if p then q' ($p \Rightarrow q$), 'q if p' ($q \Leftarrow p$) or iff p then q ($p \Leftrightarrow q$) have a truth-value. Modal logic adds a possibility-operator $\Diamond$ and a necessity operator $\Box$, but these operators are subordinated to truth-values (e.g. $\Diamond P \Leftrightarrow \neg\Box\neg P$ has a truth-value, ($\neg$ means 'not')). This thesis cannot accept this subordination, because it concerns truth (a probability) as a possibility (see *Fig. 2* on page 17), not the other way around. This thesis thus required a different possibility operator expressing that p *supposes* q ($p \Downarrow q$), to be tested introspectively as 'I cannot imagine q without p, but I can imagine p without q' (you may refer to it as a 'practical condition' to be distinguished from the linear 'logical conditions' $\Rightarrow \Leftarrow$ or $\Leftrightarrow$). This is important in education, because if a teacher want to explain q, and the student cannot imagine a tacitly supposed p, (s)he cannot 'build' upon a shared supposition p. Your 'under-standing' of q depends on your ability to imagine p, and p possibly supposes still other underlaying suppositions (e.g. $p \Downarrow o \Downarrow n \Downarrow m \Downarrow I \Downarrow k$) hidden in the words used. For a teacher it is difficult wich of them is missing before a student may understand p. This becomes particularly critical if the subject is a more dimensional image or design, where logical contradictions are allowed perpendicular to the line of verbal reasoning.

[c] Democritus(~400BC): 'λογοσ εργου σκιη'.

[d] Blind people may use the sense of touch to discover space, but this impression is also two-dimensional due to the surface of their skin.

[e] Piaget unveiled the crucial role of the motoric sense in learning. See for example Piaget;Inhelder(1947) *La representation de l'espace chez l'enfant* (Paris) Presses universitaire de France

your eyes, feet or hands. You may extend these situational descriptions through impressions of touch, smell, hearing or associated memories. But, these impressions must stay within the line of verbal inference, they must be limited to details as side-roads of the 'story'. These details may be telling in a poetical sense, but they are not sufficient to design the content, form and structure of an environment that make many actions possible. Verbal language is suited to study the content of designs systematically, to express their intended functions in a brief, to realise them in a building process, to evaluate and to sell them, but not to make them.

Studying possible environments for possible actions requires drawing

A drawing shows objects surrounding the action, for example, perpendicular to its direction. You may say that a drawing is 'at right angles' to telling a story. In Dutch this expression is revealing, because 'haaks' (i.e. 'at right angles') makes it readable as 'Drawing is *at odds with* telling a story'. Shaping an environment for many stories is different than a storyboard. A storyboard puts *one story* in a sequence of *many scenes*. It requires a different kind of imagination to make *one scene* for *many stories*. Moreover, spatial design requires that this scene must fit in an environment of many scenes for many stories, separated and connected with each other through transitions where people themselves can decide what their next action will be. The construction must be stable enough to last for years instead of hours. The structure even may hide itself from the view of the users. However, the initial imagination of it by a designer requires a thorough understanding of a third spatial dimension whereby it is released from its original imagination through movement and time. Every design student will remember that the teachers stressed the need to draw cross-sections. How can one teach these abilities, which are so strange for a mind thoroughly trained in the use of language and linear reasoning? Drawing exercises are required to release the ties of language. Drawing is an intensive dialogue between you and the developing picture that is made by your disobedient hands. Mistakes are a source of innovation. They will change your thoughts and your imagination through the act of doing. They open up other possibilities than the intended ones, which lead to unexpected directions. A picture has more directions and it is closer to the senses than a linguistic expression. Drawing allows your observations to be more free from existing categories than speaking and writing. It allows imagining categories that cannot be named. The close observation of the human heart by Leonardo da Vinci in 1509 enabled Harvey to understand the blood circulation process in 1628. James Watt designed a commercially working steam engine 40 years before Clausius and Bolzmann could understand the steam engine's thermodynamic processes.

Educating design should start by drawing and modelling

Learning by doing is broadly accepted as the intention of design studios, in design education. The tightening requirements of 'scientific education', however, forced educators to start the studios with analysis before drawing. Initial exercises trained the students in writing. In one case I know, the use of pictures was prohibited. It worried me, to see the students extending the period of analysis, writing extended reports of poor scientific quality, before they started to draw in the last days of their studio. I was disappointed by the resulting designs, which were hidden behind the overwhelming standard graphic effects that are available at any computer. The evaluation of their projects seemed to be more interested in the selling of the idea than the content. If I asked the students which elements of the earlier analysis had been useful for their design, they could not name any. The teacher's remarks on the designs at the evaluation sessions that I have attended were always expressed in words, not in drawings. I even suspected some teachers were not able to draw themselves. They were probably educated through texts rather than drawings. I even questioned my own capacity to express the relevant questions in drawings when I read my first PhD thesis. Understanding a situation and its potentials, however, first requires time consuming drawing and redrawing , in order to become aware of the questions that are relevant for spatial design. Analysis must *follow* a preliminary design, in order to determine

the relevant lines of evaluating research that are necessary to adjust the suppositions of a next design version. Design is a cyclic process of drawing, evaluating the drawing, and redrawing. Educating design should start by drawing and modelling, in order to be able to ask the relevant questions for further detailed analysis and design.

This thesis contains a paradox

This thesis demonstrates some possibilities to transcend the limits of language, but mainly through text. It may open up a vast area of research and study if this area is not primarily limited to the categories of spoken or written language. A drawing, then, must be recognised and developed as a scientific product in its own right. A drawing is a scientific achievement if it explains the intended content, form and structure properly. In this thesis, these ‘orders of diversity’ are elaborated as variables with values at the boundaries of language. This may make them accessible for traditional scientific evaluation, and it may invite traditional scientists to cross the threshold of their probability language into a world of possibility, which can be opened up through design.