Drawing as Epistemic Practice in Architectural Design

Jan Bovelet

Drawing plays a central role in architecture - not only in the critique and scientific examination of already existing architecture, but also in the conception and production of new architecture. As banal as this remark may seem, it is the correct starting point for a discussion of drawing from an epistemological perspective. There have always been works that dealt with the description of drawing techniques relative to the available contemporary practices and instruments, but something that has not frequently been selected as a central topic in architectural theory is the epistemic dimension of drawing as a genuine form of knowledge. Drawing is profoundly misunderstood if it is conceptualized as a mere illustrative instrument, and thus as a technique for representing ontologically predetermined - i.e. given - entities, with the relation between drawing and content being conceived of as one between a surface and an independent, deep structure, since, for example, different languages are only different expressions of one and the same universal grammar in Chomsky's conception of structural linguistics.[1] This conception of drawing as a tool to visualize architectural concepts completely ignores the a priori ordering capacity that lies within the epistemic dimension of drawing. Drawing is a specific epistemic practice for making architectural issues visible and thus allows for a critical examination and debate. Hans-Jörg Rheinberger described 'making visible' as central to scientific research[2] and provided a heuristic for its different modes of (a) 'compression and dilatation', (b) 'enhancement', and (c) 'schematization'.[3] All modes work by means of different symbolic practices and economies embedded in historically evolving material cultures. In order to investigate drawing as an epistemic practice in architectural design, this essay takes the viewpoint of analysing drawing from a symbol-theoretical perspective and to investigate it as a symbol system entangled with its own specific space of knowledge.

The investigation of the epistemic functioning of drawing is all the more important in the context of the digitalization of architectural drawing practices. This digitalization is intimately tied to the development of the logical analysis of language and the evolution of mathematical logic in the 20th century. In the line of Leibniz's conception of the *characteristica universalis*, the development of modern predicate logic fostered the idea of a binary logic as a basis for a universal language. This idea was particularly popular in the logical positivism of the Vienna circle. Its members aimed at mapping the natural language onto a precise, artificial language by way of substituting all meaningful sentences of the natural sentences with objective 'observation sentences'.[4] By using this method, they hoped to purge the natural language of all metaphysical sentences and thus arrive at an objective, universal language that could serve as a foundation for every science.

Digitalization led to an enormous success in what one could call the algebraization of drawing. The algebraization of drawing by means of digital

computation is based on the translation of graphical shapes into a numerical model that can be manipulated via the processing of the binary code. The digitalization of drawing into CAD, together with other digital tools such as CAM, BIM, GIS, mass customization, social design/co-design, smart houses, etc., had and has a massive impact on architecture and architectural design. In fact, the impact is so massive that it seems reasonable to not speak of singular digital techniques any more, but of an extensive digital habitat.

The idea of the construction of a universal language in the spirit of Leibniz's *characteristica universalis* gained momentum particularly through the construction of material computation machines, i.e. digital computers, in the second half of the 20th century; as, in turn, the practical availability of this technology had a huge impact on the development of theoretical logic. Notions such as, in particular, Alan Turing's concept of the universal machine 'as a model of any other machine'[5] from 1936 had an enormous influence on the conception of language in structural linguistics. With this setting as a background, Nelson Goodman aimed to develop a general symbol theory that would also include non-verbal symbol systems and allow for a comparison of all sorts of different symbol systems, such as verbal speaking, textual writing, numerical notation, musical notation, painting, technical drawing and others.[6] From this perspective, he developed a symbol-theoretical distinction between analogue and digital symbol systems that serves as a good starting point for exploring drawing as an epistemic practice.

To investigate drawing as epistemic practice in architectural design in the face of the dawn of the digital habitat, the essay has been organized into three parts. First, by way of historic examples, the epistemic autonomy of drawing and its main characteristics shall be exposed, especially its relation to text/writing and pictures/painting. Second, based on this brief historic survey, a tentative heuristic of the epistemic features of drawing shall be sketched. And third, based on Goodman's distinction between analogue and digital symbol systems, the essay closes with a critical review of the digitalization of drawing.

Historical positions on drawing as epistemic practice

The idea of conceptualizing drawing as a specific form of knowledge can be found throughout the history of epistemology, although it tended to be underestimated due to the connection of knowledge with language in the Western tradition of philosophy.[7] In the development of logic as a discipline, the declarative sentence was the paradigm of logical propositions. This paradigm has come under attack in response to the dogma of logical positivism with its programme of establishing a universal language for science. Especially Jacques Derrida has critically elaborated on the logocentrism of rational Western metaphysics in *Of Grammatology*, where he investigates the grammatical structure of writing as the beginning of all thought. Richard Rorty's proclamation of a *linguistic turn* in 1967[8] was followed by a *pictorial turn* and a *spatial turn*, both pointing to the epistemic autonomy of non-textual modes of making visible. The specific epistemic capacities of drawing will be illustrated by historic examples in the next section in order to prepare the tentative heuristic of the epistemic features of drawing.

Plato already referred to the use of a drawing for understanding universal geometric relations in his famous Meno's paradox. Aristotle also regarded drawing as a 'demonstrative description'.[9] It is remarkable that Plato was dependent on a drawing in order to make the *anamnesis* - the recovery of forgotten knowledge in the eternal soul - work: the actual material drawing is central to Socrates's maieutic instruction of the slave[10] and cannot be substituted by conceptual descriptions.

In Kant's philosophical system, a neuralgic question is how pure conceptions such as the geometric figure of the circle are related to empirical phenomena such as any drawn circle. This led Kant to the assertion that there must be some sort of mediating principle: 'Obviously there must be some third thing, which is homogeneous on the one hand with the category, and on the other hand with the appearance, and which thus makes the application of the former to the latter possible. This mediating representation must be pure, that is, void of all empirical content, and yet at the same time, while it must in one respect be *intellectual*, it must in another be *sensible*. Such a representation is the *transcendental schema*.'[11] Kant's notion of transcendental schemata is heavily inspired by the practice of drawing when he says that one 'cannot represent to [oneself] a line, however small, without drawing it in thought, that is, generating from a point all its parts one after another'.[12] For Kant, the epistemic signature of transcendental schemata lies in the figurative and in the process of their production, i.e. their status of being-in-the-making. This epistemic signature points to the fact that the epistemic function of transcendental schemata has to do with their relation to drawing and precedes the use of concepts and language.[13]

The status of being-in-the-making is also central to Charles Sanders Peirce's conception of the diagram. He sees the cognitive significance and the epistemic dimension of drawing in the interaction with the visualization, the demonstration, and the production of new insights by way of diagrams. Accordingly, for him, diagrams and diagrammatic reasoning are directly or indirectly involved in all thinking.[14]

In his *Tractatus Logico Philosophicus*, Wittgenstein formulated a distinction of showing and saying: 'What can be shown, cannot be said.'[15] He elaborated this distinction also in his later work in his exploration of reversible figures. One of his famous examples is the duck-rabbit image[16] with which he argues that seeing and thinking cannot be clearly distinguished from each other. Whether one sees a duck or a rabbit in the picture depends on which schemata are imposed upon it. He argues that we cannot see the aspect of change in the picture, but even though the image that is seen in the duck-rabbit picture is identical regardless of whether one sees a duck or a rabbit, there has to be a cognitive component in the seeing. To be able to realize this cognitive capacity, it is necessary to perceive and utilize the duck-rabbit picture. Wittgenstein uses a drawing in his *Philosophical Investigations* and asks the reader to look at it in order to show the aspect of the gestalt change. He is dependent on the use of a drawing to show the aspect of change.

These historic cases in point show that drawing comes with its own specific epistemic setting. It seems to be a kind of 'third thing', a sort of 'graphical reasoning' or 'visual thinking'.[17] But what is the specific epistemic profile of this iconic-discursive amalgam?

Following the historic examples, four aspects of drawings can be addressed: they are epistemically effective by way of their use, they are essentially generative, they mainly aim at making relations operational, and they always include some sort of non-conceptual reasoning. Reverting to the perspective of symbol theory, the question is how a symbol system must be constituted to allow for a drawing to function epistemically; just as writing, for example, has to comply with specific notational conditions, such as the syntactical identity of different instantiations of the character 'a'. In order to be able to play their role in the generation of knowledge, drawings also must follow rules that can be described in terms of symbol theory.

A tentative heuristic

Sybille Krämer sketched six basic properties of diagrammatic reasoning, on which the following heuristic of the epistemic properties of drawings is based.[18]

1 Two-dimensional flatness

Contrary to language, drawings do not rely on the temporal logic of succession but on the spatial logic of simultaneous order. Through the reduction of an extended two-dimensional plane, a drawing can reveal the relational order of different objects simultaneously, which enables the definition of differences.

2 Directionality

Also contrary to language, the representational space[19] of drawings is orientated in the sense that the topological relations of the parts of a drawing allow for orientation and are thus part of the epistemic function of the drawing. Conversely, language relies on the principle of linearity.

3 Graphism

In contrast to languages, drawings do not consist of elements, but are rooted in the act of drawing lines. Lines cannot be rendered as elements in the sense of discrete objects, as they rely on a medium that they can differentiate. This is mirrored in George Spencer-Brown's well-known opening statement regarding his calculus of form: 'Draw a distinction.'[20]

4 Syntacticity

On the other hand, a drawing is relative to language in that it works grammatically, i.e. with syntactical structuring. Although there is no finite alphabet of forms, there is always something like a relative alphabet of forms involved in the 'reading' of drawings. Re-identification of specific figurative constellations is necessary in order to use drawings to process propositional knowledge. Without this feature, drawings could not be wrong and thus could not function as arguments. Whether a composition of lines is used as a drawing is a matter of practical use: although there might be empirical differences between two hand-drawn lines in a drawing, it must be possible to read them as identical with regard to a specific end to make the composition function as a drawing and allow, for example, for arguments about proportion.

5 Referentiality

Other than pictures such as classical paintings, which present something real or fictional, a drawing aims to represent something by establishing an operational frame within which it can be subject to debate. A drawing typically refers to something external. The external reference is not necessarily something material; it can also be an immaterial quality like the openness of a figure ground plan, for example. The point being that a drawing's objective typically is to make something accessible for debate which transgresses the concrete drawing. Not always, but often, iconicity is involved in this referential quality; not in a strong logical sense of a symmetrical relation of resemblance, but in Peirce's wide sense of the word, so that, for example, a mathematical formula can represent a geometric figure.[21]

6 Operationality

Drawings do not objectively illustrate a given object or process, but they represent it in a way that opens up spaces - in the sense that Heidegger spoke of 'the opening up of […] a region'[22] - within which the represented can be handled, observed and explored. They have to be regarded as *epistemic* instruments that always also generate what they represent. It makes, for example, no sense to talk about the number Zero before there is a mathematical calculus that allows for operations with the digit '0'.[23] Likewise, it is hard - if not pointless - to talk about an architectural quality such as proportional relations without a drawing of one or the other sort as a base.

The tentative heuristic above shows relationships and differences between the epistemic *modus operandi* of texts, pictures, and drawings. Some aspects of drawings can be described verbally, whereas others cannot be substituted by conceptual descriptions. But the partial possibility to explicate a drawing by means of a text should not distract attention from the fact that this transformation consists of a translation between two different epistemic environments, which work around different epistemic objects.[24] Both environments cultivate different experimental systems. Experimental systems are the 'smallest complete working units'[25] in the generation of knowledge; in relation to their respective ends, they yield different assessments of the epistemic role of drawings and writings as regards knowledge. It is crucial to keep the translatory aspect of 'scriptualized drawings' in mind; for translations are bound to specific restraints as Willard v. O. Quine emphasized in his theses of indeterminacy, i.e. the indeterminacy of translation and the inscrutability of reference.[26] The question is what implications the rise of the digital habitat and the digitalization of drawing in architectural design have for drawing as an epistemic practice. If language and, more specifically, the declarative sentence is the paradigmatic model for the binary coding of digital data processing, and the symbol system within which drawing is embedded, is not completely commensurable with the symbol system of written language, then there are limitations to the digitalization of drawing. To tackle this issue, it is a good starting point to discuss Nelson Goodman's above-mentioned differentiation between analogue and digital symbol systems.

Drawing and Digitalization

In his attempt to develop a general symbol theory that covers both verbal and non-verbal use of symbols, Goodman formulated a distinct statement about the use of linguistic models for pictorial symbol systems such as drawings: 'The linguists' model plainly cannot be extended to pictorial comprehension. Lexicons and grammars are possible only for systems whose symbols are determinate and discriminable. For lexicons and grammars consist of generalizations that apply to symbols because they are tokens of specific syntactic types. Where it is impossible to determine the type a token belongs to, it is impossible to take it to be subject to lexical and grammatical rules. And where it is impossible to tell whether two symbols belong to the same type, it is impossible to treat them as syntactically interchangeable.'[27]

Nelson Goodman, together with Catherine Z. Elgin, drew here on the distinction of analogue and digital symbol systems Goodman developed in his epistemological centrepiece *Languages of Art*. Therein, he distinguished different symbol systems by way of their syntactic and semantic properties in order to mark their limitations in regard to different practical ends. A symbol system 'is analog if syntactically and semantically dense',[28] whereas it is digital if and only if it is 'differentiated throughout, syntactically and semantically'.[29] Only the latter can be described by means of lexical lists and the grammatical rules of valid combinations of items on that list. Analogue symbol systems, in contrast, cannot be conceptualized as consisting of a set of basic elements combined by a finite body of grammatical rules. The reason therefore lies in analogue symbol systems being defined precisely by the fact that they consist of infinitely many different symbols - which is what Goodman calls 'syntactic density' - and that there is no algorithmic way to decide whether a reference, e.g. an empirical object, complies with one and only one symbol used in the system. In a picture, for example, even the slightest nuance in the colouring can make a fundamental difference.

It is crucial to emphasize the mutual dependence of the definition of digital and analogue symbol systems in Goodman's conception. The properties of analogue symbol systems such as pictures are explicated and specified by their contrast to those

of digital symbol systems, such as written texts. Both are constituted in keeping with their different epistemic ends. Consequently, it makes no sense to ask the question of whether either digital symbol systems or analogue symbol systems have a privileged access to knowledge. Drawings possess features of both analogue and digital symbol systems. Following Kant's famous dictum according to which '[t]houghts without content are empty, intuitions without concepts are blind',[30] and Rudolf Arnheim's remark that 'the beginnings of concept formation' lie 'in the perception of shape',[31] we have to consider that concept and appearance are always already entangled from the very beginning. Drawings are situated in between the conceptual and pictorial making visible processes, with their focus sometimes more on the syntactic structuring and sometimes more on the pictorial depiction.

By drawing, traces are laid for a discourse by making a design idea visible and thus publicly debatable. The public discourse is the only scale against which a design can be judged. The notion of 'trace' has become particularly known through the work of Jacques Derrida. A trace in this sense is the marking of a difference.[32] This marking precedes writing and painting; it 'is a form of manifestation that has not yet become either writing or picture in their traditional forms. The trace precedes both of them'.[33] Digital and analogue symbol systems are sisters differentiated according to their respective ends.

Both analogue and digital symbol systems are essential to knowledge production and the organization of epistemic orientation, as long as they are used appropriately and with an adequate amount of criticality.[34] Whether the status of a symbol system is digital or analogue depends on its use; it is therefore futile to characterize digital symbol systems as precise in contrast to ambiguous analogue systems.[35] It is more appropriate to see the 'development and application of symbol systems [as] a dynamic process of analysis and organization'[36] within which digital symbol systems are being introduced, as a rule, 'once the maximum required fineness of discrimination has been settled'.[37] This shift is not an objective improvement in the sense of a cumulative progression. A digital symbol system can be discarded again in favour of an analogue one if its achievements are judged to be inadequate for the objects or processes to be examined. This oscillating shift is very common in the practices of architectural design; it can be seen in the back-and-forth movement between hand-drawn sketches and plans produced in digital CAD environments. Both design methods mutually inform each other and are developed in parallel within the design process. And to 'choose among them requires knowing how the several systems function'.[38]

To understand a digitally produced implementation plan as a purified and thus perfected sketch apparently does not make sense in this light. Both instruments aim at different ends and are constituted accordingly. From the point of view of symbol theory, digital methods are based on identical reproduction and 'chain[s] of true copies',[39] whereas analogue methods draw on the concept of difference as their guiding principle. Both aspects are needed in the design process; they mutually inform each other. Depending on the aim and the state of a design process, it can be crucial to be able to process ambiguity and thus to design in the framework of an analogue symbol system. Moreover, in another state of the same design process it can be central to being able to identify and inventorize the forms and properties of the designed objects and processes. In this perspective, the biggest threat to architectural design is the unreflected und thus uncritical application of technical methods and instruments without critical examination of whether, or to which degree, they match the properties of the designed architectural entities and processes. There is no formal solution to guarantee such matching; the appropriateness of a design tool

for a specific task can only be judged by its practical outcome. The necessity of dividing a whole into distinct units to match the requirements of a digital symbol system can never be an end in itself. CAD drawing instruments can only serve their purpose well in architectural design if they are understood and treated as means for relative, not final, ends. Establishing a design method always is committed to a cultural-critical revision of its relation to the objects and processes it makes visible; since this is something drawing in particular is concerned with.

As emphasized above, Goodman's conceptions of digital and analogue symbol systems rather need to be seen as the poles of a continuous spectrum of different symbol systems. These conceptions are crucial reference points for the investigation of drawing as an epistemic form of knowledge. Even though from an ontological point of view a definite border cannot be drawn between pictures produced in an analogue way and digitally generated drawings, they can be distinguished epistemologically by the former's tendency to always aim at presenting something without necessarily having to represent something for that cause, whereas the latter primarily aims at representing something, and in doing so, might contingently present something as well. This primacy of representation before presentation allows for a characterization of drawings as operational pictures, which stand in contrast to the denoting aspect of classical paintings. Drawings do not primarily present something through a resemblance to that which they are referring to, but rather represent something in order to take it into a discursive space through visual operationalization. They are the medium for visual thinking, to come back to Arnheim's above-mentioned notion. The epistemic capacity of drawing lies precisely in the spaces of manipulation, observation, and practice that open up by way of the operationality and performativity they establish through their way of representing objects or processes. Drawing does not consist of illustrating a genuine - and non-drawn - knowledge, but of producing genuine epistemic objects that can become the target of arguments and, eventually, objects of knowledge by way of conventional consolidation.

The observation of the epistemic role of drawings in the development of architectural design suggests that the production of knowledge is always internally entangled with the representation of the to-be-known. Dissenting from Alberti's 'new ways of design',[40] in which the design of an object or process is categorically detached from the production, drawing has to be seen as an epistemic technique 'through' and 'by' which the world is organized into entities that can be the objectives of architectonical arguments. The notion of 'argument' here must be taken literally: like textual propositions, drawings can be wrong. Therefore, like languages, operational drawings are bound to a differentiable symbol system; not necessarily to a full-blooded digital symbol system, but they need to be at least 'digitally applicable' in one respect, so that they can be read in a syntactically ruled way. This need for syntacticity suggests that parallel to the role grammar plays in language, there should be a *dia*grammatic[41] that rules the epistemic functioning of drawings. In architectural drawings, these rules are manifest in the - historically contingent - conventions of drawing practices, such as, for example, working in comparable scales or agreeing on a set of conventions over the specific use of line widths.

With this tentative heuristic of the epistemic properties of drawing in mind, what can be said about the digitalization of drawing techniques in architectural design? As an epistemic practice, drawing aims at making formerly invisible relations visible.[42] It is characterized by the possibility of shifting dynamically between analogue and digital readings, and can be judged only with regard to its practical outcome. To what extent can an unbound digitalization be a threat to architectural drawing? Sketching a figure ground plan, for example, cannot be reduced

to ordering geometric figures on a metricized two-dimensional plane. In fact, the early introduction of a metric can turn out to be counterproductive for the development of a design process. Grasping and representing a spatial relation sometimes requires a syntactically dense symbolic scheme. If a spatial relation is parametricized, it is restricted to a closed lexicon that might exclude possibilities that would have been better suited to practical needs. On the other hand, it is often necessary to restrain possibilities in order to be able to design and operate within a digital symbolic scheme where the possible configurations are limited due to the finite lexicon and the grammatical rules. A good drawing is able to make this tension operational. Following the insights developed by Goethe in his essay about the experiment as mediator between subject and object,[43] drawing has to be conceptualized not as a passive tool suitable for predetermined objects, but as an active mediating practice and genuine form of thought.

Notwithstanding all the advancements digital drawing techniques have made in recent years,[44] we have to bear in mind that different symbol systems lead to different symbolic economies tied to different epistemic conditions and 'ontological commitments'.[45] Imagine, for example, an architectural office where every member draws in the same CAD file, and this file (or printouts of it) is the only media by which a project can be discussed and developed - no pencil and paper allowed. This would undoubtedly be a profound obstacle for the design process because of the epistemological restrictions it imposes. The openness of design is essentially dependent on the shift between different epistemic practices and their related symbol systems. This openness is best cultivated by remembering that symbol systems can be addressed both as ontological and as operational.[46] To address the epistemic functioning of a symbol system, we have to understand it as being operational; to invest it with meaning, we have to take it as ontological. This is the never-ending task of critical design: to think synoptically and to be watchful about the ontological implications that operational, material procedures might have on the design.

Notes

1. See Noam Chomsky, *Syntactic Structures* (The Hague: Muton, 1957).
2. See Hans-Jörg Rheinberger, 'Making Visible. Visualizations in the Sciences - and in Exhibitions?' *MPG Preprint* 399 (2010), pp. 9-23.
3. Ibid., pp. 10-21.
4. See, for example, Moritz Schlick, 'Die Wende der Philosophie', *Erkenntnis* 1 (1930), pp. 4-11, Rudolf Carnap, 'Über Protokollsätze', *Erkenntnis* 3 (1932), pp. 215-228, and Otto Neurath, 'Protokollsätze', *Erkenntnis* 3 (1932), pp. 204-14.
5. Alan Turing, *Collected Works. Mechanical Intelligence* (Amsterdam, North-Holland, 1992), p. 112.
6. See Angela Lammert, 'Von der Bildlichkeit der Notation', in *Notation. Kalkül und Form in den Künsten*, ed. by Hubertus von Amelunxen, Dieter Appelt, and Peter Weibel (Berlin/Karlsruhe: Akademie der Künste/ZKM, 2008), p. 39.
7. Concerning the primacy of language, Frederik Stjernfelt spoke of a 'linguistic imperialism'. See Frederik Stjernfelt, *Diagrammatology: An Investigation on the Borderlines of Phenomenology, Ontology, and Semiotics* (Dordrecht/London: Springer, 2007), Chaps. 3 and 15. Another reason for the accentuation of language can be seen in the Judeo-Christian tradition of the word as being the expressive medium of divinity.
8. See Richard M. Rorty, *The Linguistic Turn: Essays in Philosophical Method* (Chicago: University of Chicago Press, 1992).
9. Here, he also speaks of diagrams; see Aristoteles, *Metaphysik*, ed. by Horst Seidl, trans. by Hermann Bonitz (Hamburg: Meiner Verlag, 1989), pp. 998a and 1014a.
10. See Platon, *Menon*, trans. by Margarita Kranz (Stuttgart: Reclam, 1994), p. 39 and the diagram in footnote 18.

11. Immanuel Kant, *Critique of Pure Reason*, trans. by Norman Kemp Smith (London: Macmillan, 1929), p. 181 (B177 / A138).
12. Ibid., p. 198 (B203 / A162).
13. This conception, which connects transcendental schemata with the drawing, is profoundly influenced by the conception of *disegno*. The latter was one of the centrepieces of the theoretical reflection about painting in the Renaissance, an aspect that has not yet been very prominent in Kant studies. A first detailed exploration of this connection is provided in Tassilo Eichberger, *Kants Architektur der Vernunft*, Fermenta philosophica (Freiburg/München: Alber, 1999).
14. See Charles Peirce, *Naturordnung und Zeichenprozeß. Schriften über Semiotik und Naturphilosophie*, trans. by Bertram Kienzle, 2nd edn (Frankfurt/Main: Suhrkamp, 1991), p. 316.
15. Ludwig Wittgenstein, *Tractatus logico-philosophicus* (Frankfurt/Main: Suhrkamp, 1963), no. 4.1212.
16. The picture can be found in Ludwig Wittgenstein, *Werkausgabe*, vol. 1 (Frankfurt/Main: Suhrkamp, 1984), p. 520.
17. Rudolf Arnheim, *Visual Thinking* (Berkeley/Los Angeles: University of California Press, 1969).
18. As this is an unpublished article, I do not quote it here, although I closely concur with her heuristic of 'Operative Bildlichkeit'. See Sybille Krämer, 'Operative Bildlichkeit. Von der "Grammatologie" zu einer "Diagrammatologie"? Reflexionen über erkennendes "Sehen"' (2009), http://userpage.fu-berlin.de/~sybkram/media/downloads/Operative_Bildlichkeit.pdf. [accessed 12 September 2010].
19. For the relation of representation and spaces of knowledge, see Hans-Jörg Rheinberger, Michael Hagner, and Bettina Wahrig-Schmidt, eds., *Räume des Wissens. Repräsentation, Codierung, Spur* (Berlin: Akademie Verlag, 1997).
20. George Spencer-Brown, *Laws of Form* (New York: Julian, 1977), p. 3.
21. Charles Peirce, *Collected Papers of Charles Sanders Peirce*, Charles Hartshorne, Paul Weiss, and Arthur W. Burke, eds., (Cambridge: Harvard University Press, 1931), CP 2.279.
22. Martin Heidegger, 'The Age of the World Picture' (1938), in *Off the Beaten Track*, trans. by Julian Young and Kenneth Haynes (Cambridge: Cambridge University Press, 2002), p. 59.
23. See Sybille Krämer, '"Leerstellen-Produktivität": Über die mathematische Null und den zentralperspektivischen Fluchtpunkt. Ein Beitrag zu Konvergenzen zwischen Wissenschaft und Kunst in der frühen Neuzeit', in *Instrumente in Wissenschaft und Kunst. Zur Architektonik kultureller Grenzen im 17. Jahrhundert*, Helmar Schramm, Ludger Schwarte, and Jan Lazardig, eds., (Berlin/New York: de Gruyter, 2006), pp. 502-27.
24. For the conception of epistemic objects see Uljana Feest, Hans-Jörg Rheinberger, and Günther Abel, eds., *Epistemic Objects*, MPIWG Preprint 374 (Berlin: MPG, 2009).
25. Hans-Jörg Rheinberger, *Experimentalsysteme und epistemische Dinge* (Frankfurt/Main: Suhrkamp, 2006), p. 25. Trans. from the German 'die kleinsten vollständigen Einheiten der Forschung'.
26. See Willard van Orman Quine, *Word and Object (*The MIT Press, 1964), Chap. Translation and Meaning; Willard van Orman Quine, 'On Empirically Equivalent Systems of the World', *Erkenntnis* 9, no. 3 (1975), pp. 313-28.
27. Nelson Goodman und Catherine Z. Elgin, *Reconceptions in Philosophy and Other Arts and Sciences* (Indianapolis/Cambridge: Hackett Publishing, 1988), p. 110.
28. Nelson Goodman, *Languages of Art*, 2nd edn (Indianapolis/Cambridge: Hackett Publishing, 1976), p. 160.
29. Ibid., p. 161.
30. Kant, *Critique of Pure Reason*, p. 93 (B74/A50).
31. Arnheim, *Visual Thinking*, p. 27.
32. See Jacques Derrida, *Grammatologie* (Frankfurt/Main: Suhrkamp, 1974), p. 109.
33. Rheinberger, 'Making Visible. Visualizations in the Sciences - and in Exhibitions?', p. 9.
34. The question of how to determine the right amount of criticality obviously has a strong ethical dimension. Although this ethical dimension is indispensable, the article focuses mainly on the logical-aesthetical dimen-

sion of drawing as epistemic practice.

35. See Jens Schröter, 'Analog/Digital - Opposition oder Kontinuum?', in *Analog/Digital - Opposition oder Kontinuum? Zur Theorie und Geschichte einer Unterscheidung*, ed. by Alexander Böhnke and Jens Schröter (Bielefeld: Transcript, 2004), pp. 7-30.
36. Goodman, *Languages of Art*, p. 163.
37. Ibid., p. 161.
38. Goodman and Elgin, *Reconceptions in Philosophy and Other Arts and Sciences*, p. 7.
39. Goodman, *Languages of Art*, p. 132.
40. Friedrich Kittler, Unsterbliche. *Nachrufe, Erinnerungen, Geistergespräche* (Stuttgart: Wilhelm Fink Verlag, 2004), p. 11.
41. See, for example, Stjernfelt, *Diagrammatology: An Investigation on the Borderlines of Phenomenology, Ontology, and Semiotics*.
42. See Hans-Jörg Rheinberger's article on the different strategies for making visible in the life sciences. He identifies compression/dilatation, enhancement, and schematization as main modes of making visible in the life sciences, and leaves open whether digital three-dimensional modelling should be counted as a fourth one. If so, it would be interesting to observe whether this would lead to a demand in architectural knowledge in the realm of natural sciences. Hans-Jörg Rheinberger, 'Sichtbar machen. Visualisierung in den Naturwissenschaften', in *Bildtheorien*, ed. by Klaus Sachs-Hombach (Frankfurt/Main: Suhrkamp, 2009), pp. 127-45.
43. Johann Wolfgang von Goethe, 'Der Versuch als Vermittler zwischen Subjekt und Objekt', in *Gedenkausgabe der Werke, Briefe und Gespräche*, ed. by Ernst Beutler, vol. 16 (Zürich: Artemis, 1949), pp. 844-55.
44. For an in-depth examination of digital drawing techniques, see, for example, Brian McGrath and Jean Gardner, *Cinemetrics: Architectural Drawing Today* (Chichester: Wiley-Academy, 2007).
45. Willard van Orman Quine, 'On What There Is', in *From a Logical Point of View* (Cambridge/London: Harvard University Press, 1953), p. 12.
46. This is Sybille Krämer's distinction. See Sybille Krämer, 'Kalküle als Repräsentation. Zur Genese des operativen Symbolismus der Neuzeit', in *Räume des Wissens. Repräsentation, Codierung, Spur*, ed. by Hans-Jörg Rheinberger, Michael Hagner, and Bettina Wahrig-Schmidt (Berlin: Akademie-Verlag, 1997), pp. 111-22 and Sybille Krämer, *Symbolische Maschinen. Die Idee der Formalisierung in geschichtlichem Abriss* (Darmstadt: Wissenschaftliche Buchgesellschaft, 1988).

Biography

Jan Bovelet, born 1980, is a philosopher (Mag. Phil.) and architect (Dipl.-Ing. Arch.). He is a member of the architecture/urban design collective *urbikon.com* in Berlin. Currently he is working for different architectural offices in Berlin and organizing the 4th instance of the exhibition series *theanxiousprop.org* as one of two co-directors.