ENABLEMENT OR RESTRICTION?

On supporting others in making (sense of things)

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Abstract. In this paper I present and reflect upon a five-year investigation of *designing digital tools for designing* in the area of architectural space grid structures. I understand design as a novelty and knowledge generating conversational process as described by Pask (see Scott 2001) and Glanville (2000). Furthermore, I regard making design tools as a design task in itself, rendering this paper a reflection on *designing for designing*. This paper gives a report on observations I made during the toolmaking study, and subsequently contextualizes these observations using second-order cybernetic theory. This reflection focuses on different relationships between observers and systems, on conditions under which observers construct knowledge and on limits of supporting others in this activity.

1. Background

Embarking on a study of digital toolmaking for design five years ago, I assumed the challenges of the subject to be primarily technical ones and aimed to tackle them accordingly. Chiefly inspired by the use of genetic algorithms in design (see Frazer 1995, pp. 57 ff.), I assumed, without being aware of it, that digital design tools could be made, offered to designers and then be picked up and applied in a way similar to the way hammers, screwdrivers or bulldozers are. In studying digital tools for designing, I initially also assumed that the tools themselves should be of primary interest, for example in order to improve their performance. But as other's studies on toolmaking and tool use in primates and children demonstrate (see Baber 2003, pp. 27-39), the qualities of the tools are not necessarily the most pertinent focus of the study. The focus should also be on us and our relationships with our tools and with our environments. The study outlined here has thus become a journey away from the technically focused development of digital design tools towards a reflection of the conditions

A Dong, A Vande Moere & JS Gero (eds), CAADFutures'07, 585-598.

under which designers make design tools to help themselves and others in making things. Having initially studied second-order cybernetic theories of design, it was only with this change of focus that I found these theories increasingly meaningful and relatable. This brief summary of key milestones in the study and their subsequent framing within some concepts of second-order cybernetic theory retraces and comments on the above-mentioned change. I emphasize some aspects of design and knowledge generation that arose as central insights such as the drawing of distinctions and of analogies, the distinction between digital and analog and the notions of pre and post rationalization. This paper follows the rough sequence of events as they occurred in the study. Observations made during the study are then reflected upon, drawing on second-order cybernetic theory. The paper concludes with remarks that may be interesting to those who are investigating or developing digital tools for designing, and to those who wish to support others in knowledge construction in general.

2. Practice: Toolmaking for Designing Space Grid Structures

The toolmaking study started off driven by a personal curiosity in natural form-finding as well as by a fascination with other designers' interest in natural form-finding processes such as those described in Thompson's (1992) "On Growth and Form". This fascination coincided with an increase in the impact of digital tools in advanced architectural practice (Kolarevic 2003) and with an interest in applying genetic algorithms to design as discussed by Frazer (1995). Regarding digital toolmaking for design as a primarily technical challenge, I approached this study in the way basic research is usually approached and commenced without attaching it to applied design projects. Due to the generic way in which it relates to design, I chose form-finding by tessellating space into grid structures as the task for which to provide tool support. This approach is based on translating packed polyhedra into grid structures by interpreting elements of grid topologies as building components such as struts and nodes (Fischer 2007a, pp. 46-47).

2.1. CELLULAR DEVELOPMENT

In the field of computer-aided design research, biologically inspired genetic algorithms have been applied as a technique for generating design variants (see Frazer 1995). In biology, developmental and evolutionary studies have recently been merged into a unified field (Goodman and Coughlin 2000) dubbed "evo-devo" in recognition of their interrelatedness in the expression of biological form. The lack of a developmental counterpart to genetic algorithm-based computer-aided design offered a starting point for the investigation of the possibility of toolmaking for a new design approach based on cellular development. Inspired by the way in which higher organisms are observed to express their tissues and organs from coded lineages of cells, I co-developed a new tool to translate user-coded digital zygotes into tissues of differentiated forms for design purposes (Fischer and Fischer 2003b). The tool, named *Zellkalkül*, was intended to allow the evaluation of the new method and to be passed on to others for application in design. It provides the user with a virtual space in which cellular tissues can develop from single initial zygotes. Cells pack closely to form tissues and can be visually represented as packed spheres, rhombic dodecahedra or as octet truss space grids. Each cell can be programmed and is able to program other cells to act as autonomous computers performing functions similar to the principles of natural cellular development. Test applications of the tool included re-modeling of the shape of Frazer's (1974) *Reptile* enclosure as well as known biological development processes, namely differentiation in the eye-disk of the fruit fly and the development of nematode embryos (Fischer et al. 2002). Producing previously known patterns, the outcomes of these exercises had little to do with novelty generation. Other, less deterministic exercises produced interesting looking "complex" patterns that, however, did not address a specific applied design project. At this point I decided to explore alternative strategies to identify possible uses of the tool.

2.2. PROGRAMMING TEACHING

As one of these alternative strategies *Zellkalkül* was applied in introducing scripting to design students without prior computer programming skills (see Fischer 2002). This educational application of the tool with its limited representational capabilities was expected to be useful for quick experiments as its constrains formal exploration, thus offering a very "controllable" design space. The tool served as a means to teach basic coding skills and as an environment to experiment with the generation of patterns of different degrees of complexity in three dimensions. Making use of only a limited set of the tool's capabilities, students requested additional features to be incorporated during the course of the subject, such as time and date functions to allow more varied results. The rhombo-dodecahedral cellular packing geometry of *Zellkalkül* is based on close-packed spheres and is not perfectly Cartesian, which posed some challenges to the visual readability of generated tissues. A more comprehensible cubic packing logic might have been more helpful in this context. Despite the possibility to execute cellular code scripts in parallel, the students focused entirely on sequential programming, that is, on scenarios in which only one single cell (usually the initial zygote) executes its code to control larger sets of other, passive cells. This choice of an "outside-in" perspective effectively contradicts the intentions underlying the tool. The students succeeded in generating unforeseen cellular patterns. Due to the limitations I encountered before, they did not use the tool for the intention-driven generation of anything of design relevance outside of the tool.

2.3. SUBWAY CONSTRUCTION

The next attempt to propose a use for the tool was to develop strategies for massively-parallel and decentrally controlled automated construction (see Fischer et al. 2003b). This approach was inspired by previous work in the fields of automated self-assembly and motion planning in swarms of robots (Yim et al. 1997), which happen to share the same rhombo-dodecahedral packing geometry as the cells in *Zellkalkül*. Yim at al. present a motion planning strategy for the self-assembly of cellular robotic compounds. It is based on centralized planning and parallel robotic motion. In reference to the underground growth of plant roots, I envisioned that cellular robotic units could "grow" structures such as subway systems without the need for centralized control. The process should not follow a precisely defined blueprint. Rather, it should aim to fulfill given requirements in a variety of possible ways. Simulating scenarios of this kind was hampered by limitations of available computing power but much more so by apparent principal challenges. Programming of massively parallel maneuvers from a central initial perspective was much more easily envisioned than put into practice. The pragmatic solution chosen in response to this problem was similar to the approach previously used by the students mentioned above. I programmed the zygote with a data structure corresponding to the intended cellular compound and to simply place cells at their target locations as opposed to instructing them in less deterministic ways to autonomously find their way. The result was not a simulation of the envisioned process but an illustration of preconceived outcomes.

2.4. PARAMETRIC SURFACE GEOMETRY

The third strategy addressed *Zellkalkül's* shortcomings with respect to its formal representational capabilities. The basic cellular units assemble into structures that are geometrically largely constrained to the system's packing geometry and produce jagged assemblies. This renders the modeling of most intended surface geometries effectively impossible and was hence seen as another obstruction to applying the tool in designing. The focus of this study therefore moved towards a search for geometrical strategies to support more flexible and detailed representations of form (Fischer et al. 2003b). At the core of this objective lies a dilemma between irregular visual appearance and the need for regularly structured coded control. Individual cells need the capacity to change their polyhedral shape while the number of each cell's neighboring positions, as determined by the underlying grid structure, must remain constant to allow unambiguous scripting control. Seven potential approaches were identified (Fischer et al. 2003a, pp. 442-443), only one of which was found to offer a practical response to the above-mentioned dilemma without involving parametric mapping onto secondary geometric shapes or involving very large numbers of cells. In this approach, all faces of the rhombo-dodecahedral cell representations are split into two triangles, allowing parametric movement of cellular vertex points as well as straight-forward data output for rapid prototyping purposes. The resulting flexibility of cellular shapes was seen in analogy to the irregular geometric assemblies observed in natural cellular tissues. However, not all parts of the grid topology permit for parametric manipulation equally. Six of the fourteen vertices of each dodecahedron are parametrically over-constrained and require a geometrically awkward workaround. As mentioned before, the programming of intended developmental processes from the “inside-out” viewpoints of a digital zygote and its descendants is a challenging task for the user of the tool. This task was now further complicated by requiring yet more differentiated control to be exerted from this difficult perspective.

2.5. BEIJING NATIONAL SWIMMING CENTRE

At this point it was taken that the conventional pattern of making generic tools for problems with known solution strategies is not likely to contribute to applied design. Hence, I sought involvement in design projects. The first such project offering itself was the space grid design for the Beijing National Swimming Centre (PTW, ARUP, CSCEC). The structure was required to satisfy the contradicting criteria of cost-efficient regularity in manufacturing and construction and visual irregularity resembling liquid foam contained in a box shape. Posing a challenge with no known solution strategy, this project gave the toolmaking study a “moving target” to relate to. The primary challenge moved away from software development technicalities towards finding possible strategies, adapting tool and outcome scenarios accordingly and evaluating them. Notably, this challenge and approaches to solving it moved temporally ahead of the toolmaking process. Only once a candidate strategy was identified did tool development start. The aspect of the design process that is concerned with making irregular shapes buildable by efficient means is referred to as geometry rationalization. The rationalization approach taken by ARUP, the engineers for the project, was based on a foam structure previously presented in response to the so-called Kelvin Problem (Weaire and Phelan 1994). This approach initially promised a high degree of efficiency (Bosse 2004), which later had to be largely renounced when the structure was cropped to form planar exterior and interior walls. Investigating geometry rationalization, which is usually characterized as pre-or post-rationalization, a third approach referred to as co-rationalization, arose in conversations with experts in the field. Before identifying new solutions in response to the Beijing project, I studied the rhombo-dodecahedral grid used in *Zellkalkül* as a potential solution for this project. The result is an irregular octet-truss derivation reported in Fischer (2005), which does however not circumscribe convex polyhedra as required for the structure to resemble liquid foam.

2.6. SELF-SUPPORTING, VISUALLY IRREGULAR FAÇADE SYSTEM

The basic topology of that approach, however, offered itself as a starting point for another applied project, which required a semi-permeable, self-supporting free-form façade. Based on previously developed code and geometry it was possible within a short time frame to resolve the packed dodecahedra into a system of folded sheet metal units, which could be assembled into semi-permeable structures of irregular appearance. Software development followed preceding strategic ideas and served purposes of evaluation, increased productivity and illustration to communicate possible outcomes. In contrast to previous work undertaken in this study from a toolmaker's perspective, I assumed the designer's perspective. I did not aim to support anybody else designing but myself. I provided design proposals for and in parallel to the project engineers, who, after testing tens of their own ideas received my proposals very positively.

2.7. GRID TOPOLOGY DESIGN

Searching for more appropriate solutions to the Beijing problem that have irregular appearances, allow cost-effective rationalization and resemble liquid foam, toolmaking was pursued with less priority. Much of the investigation now focused on non-digital strategies and I engaged more in conceptual design using sketching or just thinking as my main methods of enquiry. Another approach was to use existing tools others have made, mainly for computing convex hulls and minimal surfaces. This led to some new ideas based on systematic combination of convex polyhedra and on "evolving" three-dimensional Voronoi diagrams to approximate liquid foam geometry. These ideas are reported in sections 2.1 and 2.2 of Fischer (2007a). The idea involving combination of convex polyhedra considers configurational laws before a grid topology is assembled while the idea involving existing tools for minimal surface computation is based on generating an irregular grid topology first and then modifying it so as to conform to configurational laws. This reinforced my interest in the different approaches of pre- and post-rationalization and also in co-rationalization, which experts in the field sometimes refer to as "embedded rationale". Pre-rationalization describes a process in which the compositional system is defined before it is used in the actual design process. Post-rationalization takes a designed form and imposes a compositional system onto it retroactively. Co-rationalization is described as a process in which the compositional system is defined alongside and through the process of designing a form. This seems to indicate a new quality in design rationalization. Embedded rationale offers means for parametric transformation and exploration while possible outcomes conform to initially known material and construction constraints. After considering these approaches in relation to my previous work, I went back to the grid structures designed previously and found that some of them were pre-rationalized and some were post-rationalized. This observation in itself, however, turns out to be a post-rationalization and I began questioning if this distinction is of any operative value at the outset of a project. Can it inform a designer before there are ideas? Is any of the three more worthwhile investigating than the others? Before the application of a new idea, can it be known to which of the three approaches the idea will eventually turn out to correspond?

2.8. TEST INVOLVING TWO-DIMENSIONAL LATTICES

As co-rationalization or embedded rationale had so far not received much research attention, I decided to take a closer look at it. Following Whitehead's (2005) description of how embedded rationale was utilized in the rationalization of the Sage Music Centre façade (Foster and Partners), the approach taken was to constrain parametric variation ranges to a limited set of allowed points. As a test, this was implemented in two dimensions only, using Surface Evolver (Brakke 1992) as an engine to perform the parametric transformations. The outcome is reported in section 2.5 in Fischer (2007a). The two-dimensional test with 100 polygons was successful in terms of reducing the number of resulting strut lengths and node angles as well as in terms of achieving visual irregularity. Layering behind the resulting 2D grid a rotated copy of itself and connecting the two grids with a set of cross-beams resulted in a flat wall resembling liquid foam, which I now believe is the most successful solution to the Beijing problem so far. Turning this approach into a co-rationalizing tool I programmed a cursor based tool to assemble Kelvin cells in 3D space and to assign pressure parameters as in the 2D test. Surface Evolver, which triangulates and smoothes external surfaces of three-dimensional structures, did not yield the expected rationalization. Hence, I replaced Evolver with a small algorithm of my own, which involves no smoothing of the exterior surface. The result was once more a generic tool without project application.

2.9. TSUNAMI MEMORIAL DESIGN COMPETITION

Aiming to apply the co-rationalization approach in an applied context, the 3D tool was then applied in a project for the Tsunami Memorial Design Competition in Thailand in late 2005 together with the architects PTW and ARUP (Sydney) engineers. In this project, a sequence of foam-like pavilions was distributed along a path on the site extending into the sea. The tool was made available to the principal designer for application. However, it was operated only by myself, the toolmaker, according to agreements reached in (personal and email) conversations. During the design process, needs emerged for supporting other types of foam, alternative skinning representations and alternative data exchange facilities. The latter two of these were accomplished, while a fundamental re-programming of the space grid topology proved too challenging within the available time frame. The competition entry developed from this project did not win a prize. The winning entry of the first stage, however, also features an irregular space grid. The competition judges recommended that the space grid structure needs “more clarity.” If this was addressed at the level of fabrication and construction economics, it would imply the necessity of a geometry rationalization strategy. The further development of the winning entry, though, still does not seem to address the issue of geometry rationalization. Its success indicates that attention to geometry rationalization is not necessarily seen as being of key relevance in the evaluation of a design proposal. This corresponds to the common pattern of relegating rationalization efforts beyond proposal stages.

2.10. POSTGRADUATE WORKSHOP WITH GENERALIZED 3D TOOL

Following the Tsunami Memorial Design Competition, the space grid design tool was extended to make it more generally applicable and suitable for use by others. I have implemented support for the design of three different foam topologies and improved data exchange facilities to other 3D modeling packages. The user interface was extended for greater clarity and overall reliability was improved in order to allow others to use the tool for their design purposes. The tool was then applied in a postgraduate design workshop (Fischer and Herr 2007). The designers chose their tools according to their needs and preferences and did not necessarily comply when the use of a tool was prescribed. Observations at the workshop showed that the toolmaker’s perception of a tool’s functional principles does not necessarily reflect the tool user’s perception and intentions. Designers will likely re-appropriate tools and find their own uses for tools, ways of combining tools and interpretations of output generated with the tools.

3. Theory: Second-Order Cybernetics

The description of design as "the human capacity to shape and make our environment in ways without precedent in nature, to serve our needs and give meaning to our lives" (Heskett 2002, p. 7) is consistent with the theory of homeostasis, which states that living organisms *control* their external environments so as to stabilize their internal environments. Similarly, Glanville (1997) describes goal-seeking behavior as aiming for stability in varying circumstances. This positions the study of (toolmaking for) design in the domain of cybernetics, the theory of communication, feedback and control as presented by Wiener (1961). As an essential feedback and control system, Wiener (ibid. pp. 96-97) explains the function of a thermostat controlling a heater to stabilize the temperature of a room within certain boundaries. Below a certain temperature, the thermostat switches the heater on, above a certain temperature the thermostat switches the heater off. Either side of the control loop have identical numbers of states. Both can be "on" or "off" and the two side's states are mapped onto one of the other side's states. This leaves no ambiguity in the system. While the thermostat is often held to be controlling and the heater to be controlled, second-order cybernetician Glanville (2000) points out that the heater and the warmth it produces control the thermostat just as much. The relationship is circular and control resides between both sides. Any directionality (such as perceptions of intention or purpose) is attributed by an observer. The latter is not independent of the observed and must be considered part of it (Foerster 2003, pp. 283 ff.). By regarding something observable as stable or as instable, the observer places him/herself outside or inside of the control loop respectively (see appendix of Glanville 1997). Glanville (1996) points out that different observers necessarily observe differently but are nevertheless able to communicate as if dealing with the same observed thing. Glanville (1996) also notes that, as receiving a message is not the same as understanding it, the transmission of a message is not the transmission of the meaning. Meaning is constructed from the transmission by the receiver. Building on Pask's Conversation Theory (see Scott 2001), Glanville models novelty generation in design on the control loop, placing interacting designers at one or both ends of it. This also applies to one designer assuming both positions in different roles. With humans being capable of expressing and responding to vastly more than just two states, the conversation between designers involves ambiguity. In contrast to the control loop between thermostat and heater, design communication thus generates uncertainty and ambiguity, which is essential in making new meaning and in designing (see Glanville 2000). Glanville describes exchange loops, depending on whether they involve ambiguity or not as either "restricting" or "out of control." Accordingly, Glanville (1992) distinguishes types of computer support for designing as either (restricting) "tools" or (out of control) "media."

4. Reflection

The study took directions and direction changes I did initially not anticipate. My understanding of the design process, as well as of Glanville's description of designing as a goal-seeking behavior, has changed. Initially, I conceived of design as the uncovering of hidden set goals. Now I see the goals of design, and the path to those goals as unknowable and moving during a given design process. At the outset, I expected the study to develop in a directed, straight-forward manner. Had I had a glimpse of its eventual trajectory early on, I would have found it erratic and confused. Now, I look back at a path that, in terms of issues tackled, took numerous unanticipated turns. However, in terms of what I learned and how it will affect my approach to future projects, the path of the study appears, in retrospect, linear and directed. My ideas about design shaped the study, but the results and insights gained during the study also shaped my ideas about design in a learning process of feedback. The following points summarize the mutual relevance of the outlined study and second-order cybernetics in my view.

4.1. CONVERSATION AND NOVELTY GENERATION

During the study, I began looking at the outcomes of designing (including tools for designing) as articulations within conversations. Similarly to other kinds of articulations, such as those in language or music, there was little point in articulating design ideas without a receiver willing to pay attention. Making design tools for no applied design problem is not much different from making them for no particular user. The design process can be seen as a conversation with another designer or oneself. For this conversation to be effective in articulating design, both parties must be able and willing to listen to what is articulated, to possibly change their viewpoints, then to articulate something back to affect the other's thinking and so forth.

4.2. INSIDE-OUT AND OUTSIDE-IN VIEWS

Involvement in a design conversation entails acknowledging that the participants' ideas of the object of the conversation change during the conversation. Design project and designers change mutually. Taking the stance that the observed does not change, one takes an outside perspective, thus depriving oneself from a chance to change. Aiming to make tools for others, I repeatedly tried to position myself as controlling, assuming the other end not to change and to be willing to simply follow along the path I chose. But in doing so, I ignored that mutual changing permits and generates the ideas and knowledge which constitute designing. The postgraduate workshop showed that creating something new using a tool does not depend on accepting the tool for what it was intended to perform but on the receiver's ability to re-appropriate it.

4.3. MAKING MEANING

I also misconceived the nature of what can be exchanged in a conversation and the conditions under which the receiving end must operate. As articulations cannot contain meaning, it is up to the receiver to make meaning from them. This meaning will be different from the sender's and only thus can it have value with respect to designing. Therefore, there is on the one hand little point in controlling meaning when aiming to generate novelty. On the other hand, this shows the importance of the receiver in conversations. It is due to this side that design is an epistemological process.

4.4. ANALOG AND DIGITAL KNOWLEDGE

Receiving requires perceiving, and all perception is, at its basic level, analog. Oscillations in the air resulting in the perception of sound, changes in brightness and hue resulting in the perception of images and other sensuous stimulations are essentially continuous. Many of our articulations, however, can be perceived as discontinuous at some levels. Words, phrases, objects and other representations are used in discontinuous ways. In these cases words, phrases and objects are used as symbols in generally arbitrary, preconceived and effectively non-negotiable codes. Design seems to be an activity that takes place on the edge between the two kinds of representation, transforming continuous into discontinuous representations. Accordingly, knowledge has been described as existing in "analog" and in "digital" forms (Downton 2003, p. 65-66). This pertains to far more than the way data is entered, stored, manipulated and represented in computers. The tighter a code is controlled and the more its receivers are restricted in its interpretation, the greater is the control that the sender can achieve. The less it is controlled, the greater is the variety that can be achieved when communicating. The difference between analog and digital representations is appositely represented in Goel's (1995) distinction between a seismograph readout (analog) and a telephone number (digital). Wilden (1972, pp. 166-167) describes the activity of "mapping discontinuity onto continuity" as an "epistemological necessity." In the toolmaking study the variance of continuous representation and the control of coded representation became apparent in issues of mathematical precision and scale, the impossibility of hybrids between defined grid topologies, and in the context of words used to represent differentiated meanings to allow clear communication. The words also made it difficult to move away from what they represented.

Communication for the Tsunami competition initially made strong use of (perceived analog) visual material but eventually words like “bubble” and “façade” were used in coded (digital) ways that outsiders would not immediately understand.

4.5. ANALOGIES AND DISTINCTIONS

In coding of originally continuous and ambiguous perceptions, two elementary cognitive operations seem particularly important. One is the drawing of distinctions as described by Spencer-Brown (1997) and modified by Glanville (2002) and Varela, which can be characterized by the statement “this is different from that”. The other is the drawing of analogies as described by Lakoff and Johnson (1980), which can be characterized by the statement “this is like that.” A typical way of drawing analogies is by using metaphors, as it occurred many times in the toolmaking study. This has worked well as a means to inspire and to explain as in the case of PTW’s foam metaphor for the Beijing project. It has, however, not worked in the case of the cellular development metaphor and design. A metaphor is not the same as the phenomenon it refers to. It has no means to attain what is attained by what the metaphor refers to. Knowing developmental principles does not necessarily allow the imitation of natural processes of cellular form finding. Distinctions allow definitions and codes and are essential for control in communication. The tighter distinctions are controlled, the less ambiguous communication can become. The resulting restriction is detrimental to design when variety is reduced but can be helpful when clear communication is needed.

4.6. PRE AND POST RATIONALIZATION

Coded knowledge of something can exist before the event of communication or can emerge only after the event of communication. I found it hard to adhere to the two respective concepts of pre and post rationalization while designing but I found it easy to apply the concepts to what I did in retrospect. The idea of co-rationalization suggests the possibility of rationalization “as-one-goes.” Trying to do so, I was not able to support rationalization in this sense with the tools made in the study. Rather, I managed to support a combination of pre and post rationalization, for which the term “embedded rationale” seems quite appropriate. Examining digital (“notational”) and analog (“non-notational”) representations, Goel (1995, p. 166) refers to an intermediate third form of exchange, which he calls “discursive”. These point to what Glanville (1996) describes as meta-conversation: exchange that aims at making sure similar understandings are constructed on both sides. This type of communication controls the encoding of knowledge at the edge between the analog and the digital “as-one-goes.”

4.7. SUPPORTING KNOWLEDGE GENERATION

Relinquishing control in communication is a necessity for making knowledge and hence for designing. Both require coding of uncoded knowledge, which is a co-rationalizing process that would be difficult to code in advance and thus to implement in software. Coding requires the drawing of analogies and distinctions. These cannot be drawn for others. It is the responsibility of the receiver to make meaning. Restriction of communication is practiced by senders who do not understand or who are not interested in novelty (and knowledge) generation. Aiming to support others in these activities, designers of tools for designing are well advised to relate their work to actual projects, to draw on Glanville’s (1992) notion of design media or both. In contrast to my earlier plans, I no longer wish to support designers with design tools for projects in which I am not involved, making decisions for those whose responsibilities it is to do so. Instead, I want to share how the attempt to do so has changed me. Others who are perceptive to what I present here might agree that CAAD research needs to consider technology as a facilitator of two-way exchanges and thus exercise sensitivity towards those who are to be supported by it.

Acknowledgements

I gratefully acknowledge the feedback and support from my colleagues at the School of Design at HKPU and at SIAL at RMIT University, in particular Ranulph Glanville, my supervisors Mark Burry and John Frazer as well as Timothy Jachna.

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