DESIGN IMAGINARIES
KNOWLEDGE TRANSFORMATION AND INNOVATION IN EXPERIMENTAL ARCHITECTURE

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This article tracks the work of a group of architectural researchers and treats their experimental practices as vantages for anlayzing the social production and transformation of architectural knowledge. This requires first examining the role of so called design imaginaries *or modes of prototyping and analysis, which these researchers draw on to explore wider theoretical questions as well as test varying theories and hypotheses. It also includes examining how seemingly contradictory design concepts figure into their creative work, which we argue hold theoretical resonance with Gregory Bateson's ideas on Learning III and Yrjö Engeström's notion of expansive learning.*

Figure 1. Black, charred prototype with incised cavities

INTRODUCTION

A charred and notched block of wood the size of a fat telephone book (Figure 1) sits between two structural engineers, Nigel and Alex. They are meeting with Petra, an architect who teaches at a Scandinavian school of architecture. For the past twelve years Petra has worked with ARCH5, an international research consortium that specializes in the design of experimental architectural environments. Lately her group has focused on developing building techniques that integrate plant technologies and variegated roof systems into a common infrastructure. This includes work on so-called *roofscapes*—roof landscapes—that allow water to percolate through various soil sub-

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strates that emulate meadow or fen-like artificial habitats. But in order to create this type of shifting topography the researchers need to devise ways to control the flow of water and other aspects of their design without compromising the structural integrity of the building. The treated block of wood represents their latest design experiment, which uses "simple vector techniques" to produce an "eroding effect on the figure of the architecture."[i]

It is in this context that Petra, the architect, has traveled to London to consult with engineers Nigel and Alex about whether it is structurally possible to apply their new ideas in the design of a biotic roofscape. After explaining the project Petra looks pointedly at the engineers and asks: "How can we build with processes that we cannot control?"

This question may sound peculiar to non-architects given the common held belief that an architect's primary goal is to create designs that control rather than embrace the residual effects of external factors, like wind, rain, and heat. But as we will argue in this article this question gestures toward an unexpected perspective on the knowledge producing practices of architectural researchers. In order to understand how this question, along with the prototyping activities associated with it, can function as a productive technique for doing architectural research we must situate this interaction in a historical context. Subsequently, the question raised by Petra is of a relatively new kind for a profession that has a presence documented as far back as the third millennium BCE (Kostof, 2000). This is because her question has less to do with the pragmatics of building a building and more to do with the innovation of research methods that will lead to the development of new forms of design expertise.

Consequently, Petra is not just concerned with how the treated wood will perform structurally. She is equally interested in how this experiment can expand the frontiers of architectural knowledge and practice. By corrupting elements of their own design, Petra and her colleagues at ARCH5 are questioning conventional approaches to architecture. The wooden prototype was created, as Petra put it, to challenge the overly "mono-cultural" style of contemporary rooftop gardens by introducing an entropic element into the building's design. Here an incised piece of blackened wood is deployed as a means for exploring the tensions between durability and impermanency, between order and disorder, in architectural design.

This does not mean, however, that this experiment will necessarily become part of ARCH5's exhibited or published works, let alone instigate a paradigmatic shift in the field of environmental architecture.[ii] Those involved in this experiment take for granted that such knowledge is empiric and exploratory. In this way, Petra and her colleagues are at the forefront of a unique kind of architectural research: one that makes research equivalent to the practices of making a very particular type of design artifact. Such artifacts are commonly known as prototypes and act as a means "for reappraising the status of 'things-that-are-not-quite-objects-yet'" (Jiménez, 2013, p. 3; cf. Yaneva, 2009). In this way, this case of Petra and her colleagues speaks to a broader interest in innovative knowledge communities, something that has attracted increased attention in recent years.

As the educational researchers, Erno Lehtinen, Kai Hakkarainen and Tuire Palonen have argued, working life has become progressively more turbulent, as new forms of expertise have emerged in the face of such broad reaching phenomena, like globalization, changes in communication practices, and technological innovation (2014, p. 200). As a result professional expertise is continually under transformation. In response professionals and the organizations they work in have had to continually develop new

skills and workplace practices that have little or no precedence. In the words of Yrjö Engeström, new ways of working are "literally learned as they are being created" with the effect that "standard learning theories have little to offer if one wants to understand these process" as socio-historically influenced shifts in expertise (2001, p. 138).

In this article we will use the experimental practices of ARCH5[iii] as a vantage point into this larger issue of knowledge transformation and innovation. We aim to describe how these reserchers set up design imaginaries that have theoretical resonance with Gregory Bateson's (1972/2000) ideas on Learning III and Engeström's (1987) notion of expansive learning. What we label as such imaginaries are in this case modes of prototyping that are used by these researchers to critically examine taken for granted assumptions about design (i.e. what is possible or not) and we take inspiration from the anthropologist Keith Murphy's (2004, 2011) insightful look at the imaginary practices of professional architects. This unraveling requires first sketching out a general framework for relating the theoretical ideas to the professional work practices being anlayzed in this article. These practices we then show need to be situated within two on-going socio-historical narratives about architectural research: the first reflects on the role of making or prototyping as a form of research and the second is specific to ARCH5's intellectual commitments.

INNOVATION AND LEVELS OF LEARNING

When Petra describes the background for the experiments to Nigel and Alex she characterizes her interest as one in understanding different processes. In her words: "When you engage with the digital technologies you always have mathematical precision. Everything is in control. But how can these processes meet processes that you can't control in the same way?" As Petra's comment suggests, in the field of architecture new advancements in digital technology has given rise to radically new possibilities for theorizing how built environments are designed (cf., Parisi, 2013). At the same time that these changes have been occurring, interest in environmental/sustainable architecture has gained increasing social traction. In turn these vicissitudes in architectural thinking and practice have altered the professional outlooks of architectural researchers working in academia (Dehs & Pedersen, 2013; Nilsson, 2013). Subsequently, for researchers, like Petra and her colleagues at ARCH5, these shifts in how learning figures into the daily work routines of professionals, reflect what the sociologists of work describe as the emergence of alternative ways of organizing workplace practices.

This includes the work of several researchers, of which we will only mention a few, that have studied how these processes emerge and the forms of learning they enlist. For instance, collaborative learning scholars, Marlene Scardamalia and Carl Bereiter propose the concept of *knowledge-building communities* (1994). Based on the ideas of the philosopher of science Karl Popper (1972) they construe knowledge as a product, often in the form of models and theories, which enjoys an existence independent of individual knowers. In this way expertise is conceived of as a process of progressive problem solving and advancement beyond present limits of competence (Bereiter & Scardamalia, 1993). With their focus on shared knowledge artifacts, the individual forms of cognition are downplayed. Instead what takes prevalence are the collaborative processes involved in advancing knowledge, those actions that make contributions beyond what is already collectively known (Scardamalia & Bereiter, 1994).

Another model of knowledge transformation and innovation was presented by the organizational theorists Ikujiro Nonaka and Hirotaka Takeuchi (1995) in a study of product development in Japanese companies. They focus on the dynamics between

tacit and *explicit* knowledge where these two ends are seen as complementary entities. Innovation is conceptualized as a spiraling process arising from the interactions between the different forms of knowledge operating on various levels, from the personal level to the organizational level and back. However, Engeström has criticized aspects of this model for missing central features of innovative learning processes in work teams (e.g., Engeström, 1999, 2001). In his ongoing research and writing on expansive learning he places analytical emphasis on the social effects produced by dialectical tensions, contradictions and conflicts within shared activities (e.g., Engeström, 2007, 2011). This idea of conflict, as being a main principle and source of inspiration for reimagining design techniques and practices, remains germane to activity theory's Marxist inheritance (Engeström & Sannino, 2011). But more importantly for this study, Engeström's early writings on expansive learning drew heavily on Gregory Bateson's work on "learning to learn" (2000).

Bateson was an anthropologist and social scientist whose work intersected many different fields. He acknowledged that discourses on learning, in and between the different sciences, often and easily lead to misunderstandings (2000). To alleviate some of the confusion he proposed applying Russell's *Theory of Logical Types* to the concept of learning, which led him to distinguish between three levels of learning: Learning I corresponds to the processes of habituation, Pavlovian conditioning, operant conditioning, route learning and extinction. Bateson described this level of learning as "*change in specificity of response* by correction of errors of choice within a set of alternatives" (2000, p. 293).

The next level, Learning II, was in line with the logical types, conceived of as "change in the process of Learning I" (ibid). According to Bateson, this can happen when the contextual markers, or the contingency patterns, change during Learning I. Learning II is then the acquisition of rules and patterns of behavior that are characteristic to the context. In educational settings this *learning to learn* has for instance been discussed under the headings of the hidden curriculum (Snyder, 1970) or learning lessons (Mehan, 1979), i.e., the tacit rules that organize the social interaction of the classroom. Taken together these two levels comprise the vast majority of all learning activities. However, there can be yet another level of learning, which we argue is particularly relevant for the study of innovative practices, like those being explored by architectural researchers.

As Bateson points out, at times persons will be faced with competing or contradictory frameworks generated at level II, which he referred to as a "double bind" (2000). In a double bind situation an individual involved in an intense relationship, is caught with the other person in the relationship expressing two orders of message where one of these denies the other. This point he further illustrates in reference to the use of paradoxes in the Zen Buddhist tradition, where students are presented with "impossible" questions (*koans*) (2000, p. 303). In doing so he argues that at the third level, Learning III, there is tension that leads learners to formulate a solution. This of course is no easy task. The precariousness of the situation according to Bateson can be both dangerous and possibly pathogenic. Specifically, he argues that the situation becomes destructive when the subject is unable to find a meta-communicative strategy to resolve the paradox. But Bateson also argues that such tensions can have the opposite effect in that they can open up conceptual spaces for transformative learning experiences to occur. As he writes, "if this pathology can be warded off or resisted, the total experience may promote *creativity*" (2000, p. 278).

This is where Engeström's theory of expansive learning adds to the picture by zooming out and shifting the focus from the individual (in a relationship) to a larger col-

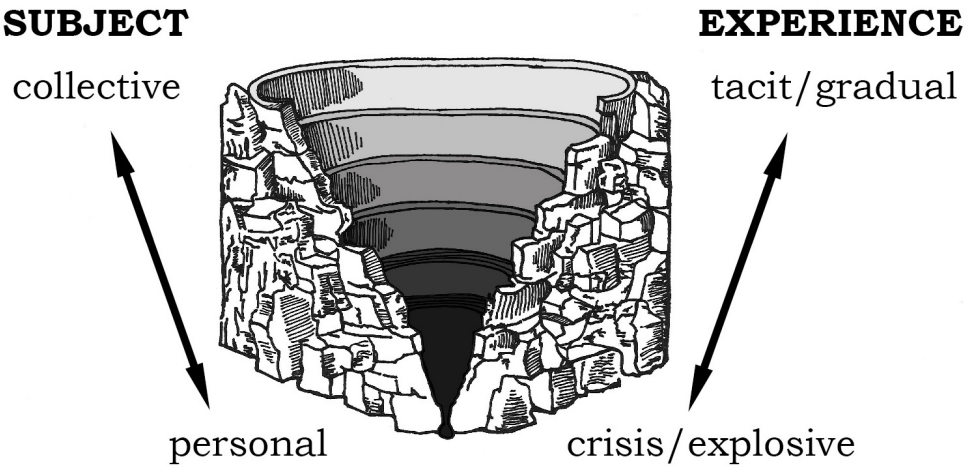

Figure 2. The gradients of 'subject' and 'experience' of Learning III.

lective (1987). In this view, "Learning III as the outcome and form of typically human development is basically collective in nature" (Engeström 1987, p. 158). At the societal level, Learning III is not experienced as so dramatic but is rather characterized by gradual developments. The effects can nevertheless be profound. In keeping with Bateson's original ideas, Engeström writes that "[b]oth modes exist – the explosive and the tacit or gradual. The problem with the latter is that it takes place in the form of unrecognized innovations, 'behind the back' of the subject as it were." (1987, p. 159). In our reading, this extension of the model can be summarized in terms of the two gradients of subject and experience, which we have schematically depicted in Figure 2. The implication here is that in moving from the individual and towards the societal level, the associated experience becomes less dramatic.

As we return to our discussion on design research we are concerned with the general idea of contradictions as they are being applied within this particular case study to reflect back upon wider architectural theories and debates. Specifically, we seek to illustrate how Petra and her colleagues draw on identifiable tensions to generate new forms of creative practice. In addition to what has been outlined above, our exposition also aims to address the origins of those contradictions and what that could mean for our understanding of how knowledge innovation is being endogenously theorized through experiments in making, especially when this is placed within the framework of architectural research.

That said, defining the parameters of architectural research is no easy task. This is in part because of the diverse range of research being currently employed by scholars, including both qualitative and quantitative studies as well as design-led inquiries (Groat & Wang, 2013). To further complicate things there has also been a radical shift in public investment in design, particularly as a means for addressing pressing social problems (cf. Fry, 2009; Hill, 2013; Cruz, 2013; Rendell, 2013; Rubbo, 2010; Søberg, 2013). This in turn has inspired a number of important educational reforms, along with the adoption of social policies aimed at strengthening the link between research and practice, particularly in the U.S., Western Europe, and Australia (Dehs & Pedersen, 2013; Nilsson, 2013; van de Weijer, van Cleempoel, & Heynen, 2014). As a result the field of design, in which architecture is included, has gained considerable social and political traction. But it has also raised serious questions about how to define the parameters of research in architecture.

In addressing these concerns design scholar Fredrik Nilsson explains that architectural researchers have turned a reflexive eye to their own, specialized skill-sets rather than merely appropriating methods developed by outside disciplines. He writes:

> In attempting to gain a more in depth understanding of these objects and processes, architectural research borrowed theories and methods from other disciplines, sometimes without reflecting on the specific character of architecture as a discipline. This eventually led to a strong critique from both the profession and from academia, and a growing need to develop more articulate conceptual and theoretical frameworks relevant to the specific field of architectural practice and research (2013, p. 3)

Consequently, *making as research* or *research through design*—two phrases we use interchangeably to describe the aesthetic, material, and immaterial exploration of theoretical problems through architectural processes—has gained increased currency in investigations of architectural practices. While these issues are still being debated, what has become clear both within and outside the discipline is that producing knowledge through making allows researchers to draw directly on their highly specialized and embodied ways of knowing (Pallasmaa, 2009). It is with these embodied forms of knowing in mind that we return to the meeting between Petra, Alex and Nigel as they scrutinize the different prototypes.

Figure 3. The architect Petra together with the construction engineers Alex and Nigel

THE GENEALOGIES OF ARCH5'S ENTROPIC EXPLORATIONS

Moving her fingers across the irregularly patterned grooves of one the prototypes sitting on the table before her, Petra begins explaining to Alex and Nigel how their features differ. Pointing first to a white plastic 3D printed model, she describes it as having "a kind of pure geometry." That, she tells them, is "what we're *not* interested in." But the features of two wood prototypes, which have been processed in a CNC (computer numerical control) mill and subsequently charred to varying degrees, are, she explains, what ARCH5 is most interested in because the process used to create those forms have allowed them to "corrupt the geometry" of the wood. "That is what's interesting; to make the impossible, possible," she adds with a note of excitement in her voice as Nigel and Alex nod their heads enthusiastically.

In this exchange Petra links the affordances of the prototypes to particular ideas and theories about design. These ideas and theories have been generated within the wider

field of architecture but also through the experimental work that ARCH5 has been conducting for the last twelve years. Yet, what exactly does Petra mean when she says that the geometric shapes of the white plastic prototype are less interesting than the corrupted forms produced by the CNC mill? Moreover, what is the connection between the geometrically corrupted prototypes and ARCH5's experimental work on biotic roofscapes? As will become evident, discerning the full meaning and intentions behind these distinctions requires reflecting on the history of ARCH5, organizationally but also epistemologically. In doing so we seek to underscore the necessity of showing how the mediated forms of communication analyzed in the following section are direct by-products of ARCH5's on-going research.

Historically, ARCH5's research interests in environmental design can be traced back to a number of emergent technologies, scholarly theories, and artistic movements. For instance, in the late 1990s when Petra and her colleagues first began working together, Internet technologies, like BitTorrent and Flickr as well as open source platforms, such as Moveon.org, became a critical source of inspiration for their thinking. These technologies, or more specifically, the ways in which they allow for information to be exchanged, offered up a powerful set of models for thinking about architectural networks. The capabilities of these networks, they speculated, could greatly transform material-environmental relationships in architecture, especially if these systems exceeded purely circulatory functions.

But in order to pursue this goal ARCH5 has had to identify theories and practices that would allow them to transcend conventional thinking in architecture. Central to this effort has been the notion of "reflexive communication"[iv]—an idea inspired by the work of Billy Klüver and Marshall McLuhan, who have greatly influenced the group's thinking on sentient and non-sentient based forms of inter-communication. This concept asserts that networks have the ability to do more than simply move data from one place to another. Rather by creating a context for exchange, new interactive spaces can emerge through which distinct assemblages of knowledge can be generated and distributed across time and space.

This proposition, however, was on its own only partly helpful. Other concepts were needed that would aid in the design of an infrastructure that could not just accommodate but synthesize these seemingly incongruent processes, a concern further complicated by the fact that the algorithmic modes of measurement that are used to assess heat and moisture levels in buildings are radically different than the modes of energetic exchange produced by living plants. As a result it became clear to the researchers that the design of the interface would have to transverse varying assumptions inherent to architectural design, including the idea that erosion and other forms of decomposition are adversarial to good design. What if, they asked, we innovated a way of fabricating built environments that permitted (to a certain degree) these processes to occur, rather than trying to control or stop them from ever happening?

To this end the avant-garde theories of Kisho Kurokawa, who perpetuated the notion of entropic design, became a critical source of inspiration for ARCH5. His writings on metabolism and metamorphosis in architecture became integral tools for recognizing how the atmospheric conditions of built environments are shaped not just by the materiality of a structure, but also by the underlining axioms of permanence and fixedness that schematically structure design thinking, particularly in the West. These conventions, Kurokawa goes on to argue, are conceptual forces that structure design processes in ways that are often not recognized because they reflect deeply seated cultural beliefs about architecture. As he stated in his famous Capsule Declaration,

"The classical school of city planning and architecture saw the job of the architect as negentropic, as running counter to an increase in entropy" (1969/1977, p. 84), and to Kurokawa, these ideas had to be challenged.

This thinking, coupled with the notions of networking and reflexive communication described above, provided ARCH5 with the necessary conceptual tools needed to develop a language for talking about and ichnographically describing entropic processes in architecture. Consequently, it is in this light that we come full circle to the prototypes being analyzed by Petra and the two structural engineers, Nigel and Alex. These prototypes were created as part of a design brief for a multipurpose building that could serve as an educational meeting space, while also showcasing state-of-the-art design techniques. In the next section we will turn to an in situ description of the contextualized exchanges between the participants.

PROTOTYPING AS PRACTICAL ACTION

Launching into a description of how the wooden prototypes were produced, Petra explains to Nigel and Alex that the experiments started with the idea that they needed to "let go of certain aspects of the design process." And since they had access to a CNC mill they decided to hack it by altering the path of the mill's rotary cutter. The ordinary way of operating the mill would have been to let the CAM software generate a physical object with close resemblance to what the digital model prescribes. But by altering the path of the rotary cutter ARCH5 was able to produce multiple and unevenly distributed incisions across the surface of each of the wooden blocks (Figure 4). Since the number distributed vectors (as infinitely thin lines) did not contain any information about the physical dimensions of the rotary cutter used in the mill, this alternative method of programing introduced uncertainties into the outcome. As Petra put it, "we only had control of the mill, not the end product."

By describing the processes used to produce the prototypes Petra sets the stage for a discussion that will extend for close to two hours and touch on multiple project-related concerns. For the purposes of this analysis we will focus only on how the participants analyzed the prototypes in order to further their understanding of en-

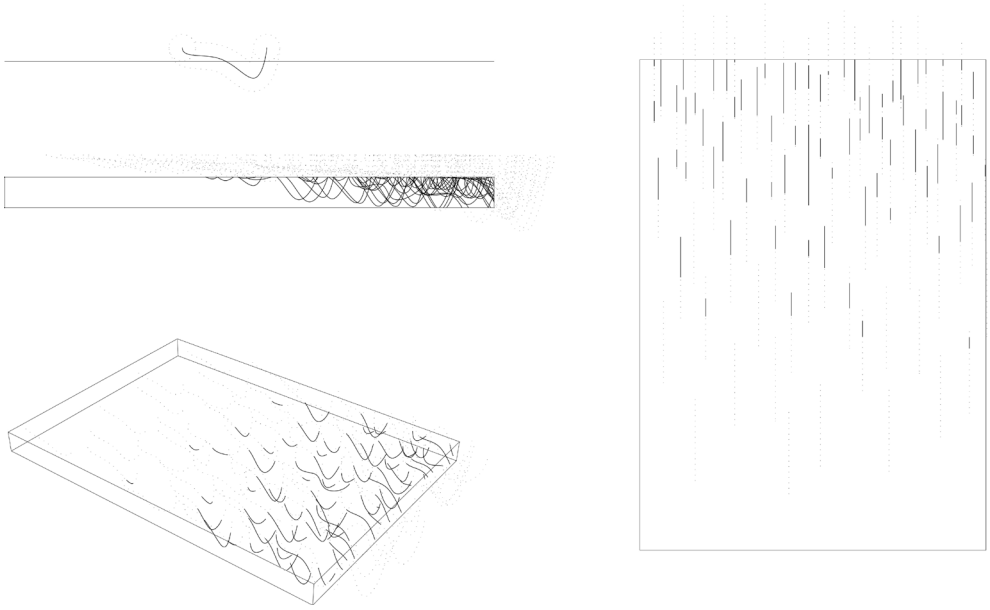

Figure 4. Diagrams of vector tool-path

tropic design.[v] And since there are no direct precedents that Petra, Nigel or Alex can draw on, they need to identify a line of reasoning that will convincingly illustrate to both themselves as well as outside specialists that it is "possible to build with processes you cannot control." Analytically, this means attending to these experts' own methods for conducting architectural research, the so called *members' methods* (Garfinkel, 1967; Garfinkel & Sacks, 1986). Specifically, we want to draw attention to three analytical techniques that structured the interactions of this discussion. They include:

1. An assessment practice that would search for and try to recover potential qualities generated by the prototypes' production, which we will refer to as a *locally produced mode of scrutiny.*

2. The formulation of a *mode of attention* for imagining how the inherent qualities of prototypes will perform under varying conditions.

3. The use of the word "interesting" to mark certain design aspects in merit of future explorations.

Taken together these examples illustrate the "concrete ways in which a shared common sense operates within" this charrette (Francis & Hester, 2004, p. 195). Or put more simply, how experiments in making are turned into architectural research through social exchanges, like the meeting being analyzed here.

A Locally Produced Mode of Scrutiny

As Petra's explanation of how the prototypes were created ends, the group turns briefly quiet. Suddenly Nigel breaks in by saying: "Okay we have to think about material. Personally I like the idea of wood. It's a material of the future rather than the past. In Scandinavia no one is afraid of it but they are not using it like they should use it. It makes all of those things easier. Its lighter it's all sorts of things." To which Alex adds, "I think probably wood is one of those materials where everyone uses it but they actually all use it in the same way. But showing different ways of using wood will completely blow people's minds."

In this exchange the subject of wood becomes a staging ground for framing conventional approaches for using wood in architectural designs as ineffectual or less desirable for achieving the types of design outcomes that ARCH5 is searching for. In the process of problematizing these conventional practices the irregularly incised wooden prototypes become less alien and more recognizable. In this way the fabricating methods used by Petra to produce the prototypes are aligned with certain values and ideals, which though never clearly defined, are nonetheless alluded to in the conversation as groundbreaking and socially imperative. As such Petra's question: "Is it possible to build with processes you cannot control?" is inverted. It becomes an organizing principle or source of inspiration rather than a mere thought experiment.

The unknown, the untested, the unconventional, in other words, can yield its own investigation, which both Nigel and Alex capitalize on by pointing to the benefits that might be gained by using wood: "It makes all of those things easier. Its lighter it's all sorts of things." These interactions create a locally produced mode of scrutiny that in turn open the possibility for other modes of attention to emerge, which brings us to our next example.

Accidents as a Mode of Attention

In this interaction Petra outlines some of her interests in what materials can offer to the design process. "Perhaps there are inherent aspects in the material, that effect how some- I mean it could be material properties for example the grain of the wood. Or

in a ceramic process you have shrinkage, and you have- things happen… And how can one think of these processes as," "productive" interrupts Nigel and Petra adds in agreement, "as productive. Like processes that you don't control."

Here Petra explicitly addresses a specific attitude towards the process of making and speaks about the unforeseen happenings when working with different materials. In their dialogue, these events are collaboratively being recognized as potentially "productive." Somewhat later in the discussion, Nigel returns to this issue and he then talks about it in terms of "accidents" and how they can be turned into selling points for the project at large. By way of this categorization he positions this interest—in uncontrollable aspects of making—into a longstanding discussion about "the deliberate accident in art" (Turner, 2011); a history at least going as far back as Leonardo da Vinci.

As art writer Christopher Turner (2011) points out, historically Western artists have seized "on the tension between accident and intention" and used this tension as inspiration, though in varied and ideologically distinct ways. In a similar manner, accepting the coincidental was a technique embraced by ARCH5 in their prototype development. For instance, after the prototypes were produced they were subjected to a specific mode of scrutiny, an assessment practice that would search for and try to recover potential qualities ensuing from the previous loss of control that was created when the CNC mill was hacked. In this case it was discovered that, in the translation from the digital realm to physical reality, the cuttings made by the repetitious movements of the mill would sometimes intersect. As a result, the prototype would exhibit cavities of a different complexity compared to what could be discerned in the diagram (Figure 3). These interference patterns manifested in cavities and niches were deemed productive and later used to name the project *Vector Interference*.

Finally we turn to the last analytical technique that was used to structure the interactions between the participants in the meeting; the formulation of topics for further investigation.

Formulating "Interesting" Problems

In the following exchange the architect Petra is drawing on one of the other prototypes she has brought to the meeting: a white 3D printed plastic scale model showcasing the general geometry of their building's multiple catenary roof structure. As we will show from the uptake of the engineers, the word "interesting" is used as a resource to mark certain aspects of the construction that should be explored further.[vi]

"If I would apply *this*," she says, pointing to the incised surface of the charred prototype, "on to here", now tracing her index finger along the arched roof structure of the smooth sintered plastic model, "this would perform structurally?" "Yes," responds Nigel, "that's what you would aim to do. You would apply it to make sure it performs structurally. Which would be about scale, curvature, [and] shape." "Yeah," answers Petra to which Nigel adds: "Because a lot of this is in [the] shape. What is interesting about this is that wood doesn't really like tension; wood likes compression. So you know to force it to do that is quite interesting." Shaking her head in agreement Petra says "Okay."

Petra's tentative suggestion to incorporate the cavities of the wood prototype onto the general geometry of the roof, in a structurally sound manner, is in search for confirmation by the structural engineers. Rather than simply aligning with her suggestion, Nigel opens up this point for further elaboration. First, he is establishing this particular issue as one of the central problems that the proposed project will have to work with. Furthermore, this contradiction between tension and compression, is not

simply a problem, in the sense of an obstacle that has to be cleared; it is also marked as an "interesting" problem. In this way, the charrette fulfills one of its purposes, which is to identify some uncharted territories of knowledge, as possible candidates for future research investigations. The justification of this problem as "interesting" is again connected to the inherent properties of the chosen material of wood. This time though, the solution will have to pursue a line of inquiry in which the matter of control is reversed. Here it is not about listening to the material biases, but rather to "force" wood to do something it does not "like."

In summary, the three examples illustrate how the emerging project around the innovation of techniques for "building with processes you cannot control" became concerned with fostering an increased sensitivity to material and organic processes, which entailed exploring ways to accommodate uncertainties. At the same time, Petra, Alex and Nigel also searched for new methods for "disciplining" the materials and thereby controlling for new performances. Not only were these investigations to be pursued in themselves, they also had to be organized in relation to the general aim of the project, which sought to incorporate environmental performances in the architectural system. The activity of making diverse inquiries coalesce became a central part of the theoretical work of the group and key in their articulation of a theory that would sustain a consequential relation to design. This interplay between particular material inquiries and objectified abstractions is where we turn next.

TRANSACTIONS IN ARCHITECTURAL RESEARCH

To this point this investigation has set out to explore the knowledge producing practices of architectural researchers during a design charrette. In this section we want to move the discussion slightly beyond the meeting and turn our attention to the interrelations between, what we will speak of as, the *lived-work* of design and material experimentation and its *theorized renderings*. Two analytical concerns can be drawn from the examples analyzed above. The first is interested in how material investigations in architectural research are initiated, controlled or informed by the theoretical interests of the researchers (e.g. ideas about entropic design). The second seeks to elicit the ways experiences from experiments in making are collected, enriched and translated into textual forms. That is, those objects that survive as frozen records of communicative encounters.

First, let us consider how theory instigates action. From our perspective, the studied theorizing is in itself a practical enterprise, which first and foremost operates through communicative exchanges.[vii] The developing theory of entropic architecture—*building with processes you cannot control*—partly worked by setting up a linguistic register, which would aid topic selection. The register could be seen as projecting a conceptual space of options, as offering a realm of contradictions and problems to investigate and explore. In this way the register not only informed what Petra, Alex, and Nigel said to one another but it also influenced the modes of attention and temporal lines of reasoning that they used to analyze the prototypes. Furthermore, by continually curating the register, through the selection and prioritizing of items, the researchers also worked to give the larger conceptual enterprise a sense of direction.

However, such general concepts, if they are to be functional as principal constituents of the theory, must be possible to operationalize. That is, translated into researchable things and projects, and, for ARCH5, these translations became one of the key elements in closing the gap between theory and practice. The notion of *control* is a case in point. As we have shown, to willingly give up part of the control in the process of

making was a theme that appeared repeatedly throughout Petra, Nigel and Alex's discussion. At times, the condition was engendered through the procedural work on the prototypes, as in the case with hacking the CNC mill. In other instances, the idea was to search out and incorporate environmental forces pushing the architectural systems towards a state of disorder.[viii]

This brings us to our second concern: How do ideas and insights travel from various experiments and discussions and find their way into more durable formulations? For instance, at certain points, both the production of the prototypes and their evaluation were bracketed and subsequently put under examination as processes in their own right. By topicalizing their own work practices, the gaze was lifted from the immediacy of the material prototypes and shifted to the long-term aspirations of the design project (i.e. identify a technique for fabricating a roofscape that "embrace entropic instances and corruption"). In order to enable this shift in orientation, events and procedures were generalized and typified as *forms of processes*. The most important distinction introduced here was that between processes with numerical control and processes where some control was lacking. In this way the qualities produced by tampering with the CNC mill was not simply seen as a one-off event but also as pointing towards a class of *generative outcomes*, collected under the rubric of *effects*. The deployment of this meta-language thus enabled the articulation of a more generalized research interest pertaining to, as Petra put it, "the interplay between different types of processes and its resultant effects." The move of elevating *the uncontrollable* to central tenet also became a way to put the work in connection with, and critically dialogue, Kurokawa's (1969/1977) historical program, as well as more contemporary discussions on algorithmic design (cf. Sakamoto & Ferré, 2008).

The outcomes of these attempts towards generalization were later given textual form in: written design briefs, exhibit documents, and scholarly articles. Abridged for current purposes, the concepts and concerns became formulated as:

- An experienced exhaustion of the precisely figured when coupled with machinic[ix] processes for fabrication.

- A reaction to the notion of *construction as negative entropy*, and the alternate suggestion to instead embrace entropic tendencies.

- An interest in the relation between synthetic systems and organic matter.

- An emphasis on transactions with matter: A return to the traditionally suppressed intrinsic biases of materials.

- The incorporation of environmental performances.

We take these formulations to be exemplars of this particular profession's *theorized renderings*. With this we mean such concise conceptual descriptions that will only be fully understandable to members that also share the profession's methodic practices. For all practical purposes, the formulations are adequate, disengaged descriptions that gain their relevance from within the lived, temporal course of experiments in making (cf, Livingston, 1987). Even if they are only accessible/recognizable to a small community of researchers, these textual renderings circulate a number of design ideas with varying acuity. And it is within these artifacts that we find the articulation of what could be seen as an emerging program for entropic architecture.

DISCUSSION

In reflecting on how meaningful insights in this research setting come into being this article has drawn on a video and audiotaped analysis of Petra and her colleagues as they analyze the technical and aesthetic qualities of a series of prototypes. The social exchanges that make up this interaction provide a critical vantage into how expertise, along with material and aesthetic concerns, amalgamate and produce intersubjective understandings or conceptual models for theorizing design processes that generate new possibilities for incorporating plant technologies into the design of roofscapes.

When setting the scope wider, the work of ARCH5 can be seen to continuously search out, topicalize and explore complex design phenomena. In the aggregate we find their investigations trained on systemic features that verge on the incongruous or contradictory. Consequently, a number of their formulations talk of "accommodating for the un-controllable", "embracing the coincidental" or "letting the geometries become corrupted". If we approach these formulations through their linguistic expressions, we can see that they systematically connect a certain set of *transitive verbs* with a specific class of *direct objects* (in the linguistic sense of the term). And it is this relation that we hold to be relevant in connection to the previously introduced discussion on Bateson's conceptualization of Learning III and the closely related notion of expansive learning.

Starting with the conceptual language used to analyze the prototypes that Petra has brought to the meeting, we see how she and the two engineers evoke a series of linguistic objects along the lines of: "contradictions", "the entropic", "the coincidental", or "the disorderly". While differing to a certain extent in the way they describe aspects of the design work being evaluated, what they have in common is that they all target circumstances under which a subject is put into some state of *non-control*. In other words, addressed in one topic after another are the very material conditions that are thought to characterize double binds. The accompanying set of verbs that are used to descriptively connect both the current and historical work of ARCH5 with these processes take forms like "invite", "embrace", or "accommodate". This suggests a certain predilection or directionality in the described relation. Rather than remaining reactive or controlling the interpretive borders of their designs, ARCH5 actively expose, both their own work processes, as well as the architectural systems, to the unexpected. As a result, by systematically manipulating the premises that influence their work, the researchers can set up what we have called *design imaginaries*, situations that approximates self-inflicted double binds. The idea of engaging in this form of conceptual experimentation is of course to exploit this mode for its creative potential. But, although "driven to level III by 'contraries' generated at level II" (Bateson, 2000, p. 305) any resolution through transformative accounts or interpretative interventions are never guaranteed. Such resolutions of contraries can only be accomplished by way of innovative leaps, certain moves that make previously unknown connections conceptually possible. As Bateson noted, one way forward, or the healthiest way to recover from a double bind, is typically by producing a meta-language (2000, p. 215). On this note we find some resonance in the ways in which experiments and work practices were synthesized by ARCH5, as for instance in their search for *types of processes* or in their collection of *generative outcomes*.

In conclusion, these and the other examples outlined in this article point to the experiential dimension connected to Learning III (see Figure 2). As Engeström (1987) argues, some transformative developments at the collective and societal levels may not

be fully experienced by an individual subject as they appear as more gradual or tacit. As a contrast, we believe that this case study comes close to the individual and explosive mode described by Bateson. Even so, we would argue that there are two aspects that, metaphorically speaking, function as safety valves. The first is the knowledge that the contradictions facing Petra and her colleagues are in place by their own choosing. Unlike the subjects in most of the examples put forth by Bateson (2000), as well as many of the situations described by Engeström (e.g., 2001, 2007, 2011), ARCH5 has actively sought out and engineered their own circumstances for generating expansive learning interactions, by producing design models and conceptual registers that are purposely contradictory. In a certain sense, this means that they are in control of their loss of control, which is in itself a meta-communicative resource. Second, ARCH5 has a long history of working on similar projects and problems. This means that there is a degree of confidence that has been produced through their past experiences conducting research experiments. Thus, it can be argued that while inhabiting the space of Learning III Petra and her colleagues are also drawing on their previous experiences with the unknown. Part of their expertise as designers and researchers is reflected in their capacity to endure such uncertainties while remaining confident that some resolution *will* emerge out of their experimental practices.

NOTES

i) The language used to describe the architectural design of this project is taken from a design brief ARCH5 created after this meeting.

ii) We are using the word "published" liberally here, ARCH5 does publish written work based on their research but they also give lectures, create multi-media platforms, and exhibit their research in galleries and related venues. At the time of this publication a design brief on this project has been made public via the ARCH5 website. But the point that we are underscoring here is that at the time that this charrette was carried out the future of this experiment was not known, it was still being explored and tested.

iii) The study results from a longitudinal ethnographic investigation that began in 2011 and was carried out Ivarsson. For close to five years the research team (here called ARCH5) have been followed across the world and their participation in various activities have been documented. Everything from collaborative work meetings, modeling sessions, interdisciplinary design dialogues, to material testing, teaching and course assessment, as well as exhibitions and faculty talks have been observed and video recorded. In addition, a whole range of images, sketches, drawings, 3D models, briefs as well as several texts produced by the group have also been collected and analyzed. Nicewonger joined the project in 2014.

iv) ARCH5 has described these ideas and their historical impact on their work and the field of architecture more generally, in a number of published texts. But due to issues of anonymity, we have decided not to directly quote or cite these sources.

v) In addition to discussions about the prototypes the three actors also discussed in great length the geographic location of the proposed site and how to best communicate their design ideas to varying stakeholders.

vi) For a critical analysis of how the term "interesting" figures into the work of artists, theorists, and literary writers see Ngai (2008).

vii) We recognize that both verbal and nonverbal forms of exchange are being performed in these interactions. But for the purposes of this article our focus is on the language practices being used by these actors to talk about the prototypes.

viii) Examples of such discussed environmental forces would be the long-term spreading of moss spores across a manufactured surface, or, ways to use frost weathering of ceramic roof tiles as an emerging medium for the establishment of a substrate for a green roof.

ix) With this spelling ARCH5 alludes to the notion of "machinic assemblages" found in the works of Deluze and Guattari, e.g. A thousand plateaus: Capitalism and schizophrenia (1987).

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