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Architectural Research Paradigms – an overview and a research example

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Abstract

As Architectural Research is in the process of re-establishing itself as a research discipline according to university standards, it may appear as if the pool of knowledge generated by more than three millennia of experimental research and its internal systems of evaluation are being grossly devalued and colonized by attitudes to research that are imported or even imposed from the outside. Does architectural research have to rely on imported theory from philosophy, the social or the natural sciences in order to meet societal acceptance of its relevance? What constitutes architectural research as a particular research discipline, what are its main characteristics and how can its paradigms, methodologies, strategies and tactics be described? What should be essential aspects of doctoral curriculae in architecture?

Discussing Groat and Wang's *Architectural Research Methods*¹ in the light of *Reflected Practice*², and *Organizational Knowledge Creation*³, a framework is presented that includes evolving paradigms and art in architectural research, and demonstrate how this framework allows one to describe the paradigmatic shifts that happened during the course of a PhD research project involving cross-disciplinary teamwork.

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¹ Linda Groat and David Wang, *Architectural Research Methods* (Wiley, 2001).

² Donald A. Schon, *The Reflective Practitioner: How Professionals Think In Action*, 1st ed (Basic Books, 1984).

³ Ikujiro Nonaka, 'A Dynamic Theory of Organizational Knowledge Creation', *Organization Science*, 5 (1994), 14–37.

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Fig 1: Marcel Duchamp, Three Standard Stoppages 1913-14. MOMA New York

Architectural Research Characteristics

Judged by a notion of classical positivist science emphasizing objectivity, internal and external validity, the normative stance that characterizes most architectural discourse and theory is questionable, disqualified by its inherent bias. In this understanding architecture belongs to the arts, and does not qualify to the high status of science. On the other hand, viewed from a position in the arts, science is sometimes seen as less creative than the arts including architecture, dealing only with found facts⁴.

But is it really possible to distinguish so sharply between science and art? It depends on what is understood by the terms, and in that respect the subliminal weight that the recent history of the dominant positivist scientific paradigm and the avant-garde in the arts carries in the collective imagination should be realized. Now the traditional dichotomies of arts and sciences are in a process of transformation:

As **Kwinter** points out⁵, applying a purely positivist notion of science to architectural research would be an extremely difficult position to maintain now. Instead Kwinter's notion of science is

⁴ Sanford Kwinter, 'Sanford Kwinter on: Science and Architecture', 2007, p 11
<http://www.manifoldmagazine.com/Manifold_01.pdf>.

⁵ Kwinter.

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shifting towards a general idea of knowledge: “*Science is about model building, not facts. Every experiment is a model, a form imposed on a piece of world to produce an effect, isolate a behavior, generate a fact that can be transposed to another milieu. ... Any practice ... which approaches this place and world with something other than a superstitious and magical attitude, is fundamentally science.*”⁶In Kwinter’s view it is the model-building capacity of architecture understood as *gedanken-experimente*, the creation of ideas, narratives and physical reality that makes it scientific. But can we equate science with qualified knowledge? How should that knowledge be qualified?

If the introductory hypothesis that architectural research is besieged by other research approaches is justified, - assuming that for a moment – What are then the characteristics of architectural research per se? A closer look at the beginnings of architectural theory may surprisingly act to confirm a radical contemporary position like Kwinter’s.

The opening phrases of **Vitruvius**⁷’s first book of architecture remind us of the fundamentally multidisciplinary understanding required by the architect (arkhi-tekton – from greek: master-builder⁸) which is not only necessary in basic architectural education as Vitruvius argues, but is imperative in architectural research education too, a point which will be argued in this paper. A remarkable aspect of the latin original is the connotations surrounding the concepts of science/knowledge, theory, practice and arts. It is hard for a contemporary reader mentally to dissociate the words science and art from the particular 20th century meanings ascribed to them, which arose from the antithetical positions of positivist science and the avant-garde in the arts, and we may not fully understand how the terms were understood then either. The role of the architect has changed too. The city planning, temple constructing designer of water-clocks and war-machines has fragmented into a wide variety of contemporary professions counting architects, engineers, industrial designers and more.

But the core of the discipline as described by Vitruvius surprisingly similar today:

⁶ Kwinter, pp 11-12.

⁷ Vitruvius, *The Ten Books on Architecture*, trans Morris, 1st, 1960 ed (Dover Publications, A.D. 15).

⁸ ‘Online Etymology Dictionary’ <<http://www.etymonline.com/index.php?term=architect>> [accessed 13 April 2011].

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“The architect should be equipped with **knowledge** of many branches of study and varied kinds of learning, for it is by his judgement that all work done by the other arts is put to test. This knowledge is the child of **practice** and **theory**.”⁹

Scientia is here translated generally as knowledge, while arts are associated with fabrication and practical skill. The relation to technology is obvious, the greek roots of the word *techne* – art, craft or making, and the suffix *-logia*, meaning study or theory¹⁰. But what is particularly revealing in a contemporary interpretation is the term that is translated with theory. Ratiocinatio means not only theory but is also a particular figure used in rhetoric, referring to a process of reflective reasoning: One makes a statement, questions it, and answers the question, to achieve rhetorical effect¹¹. What is important here is the emphasis on reflection and rhetoric purpose, a point which seems to have been unnoticed in previous readings.

The aspect of rhetorical effect in ratiocinatio can be seen as surprisingly similar to the emerging acceptance of polemical theory in the social sciences, which will be explained in the following. The intricate connection between practice concerned with fabrication and reflective reasoning as the constitutive parts of architectural knowledge, has only recently been reintroduced to research theory as *reflective practice*¹². The architectural research community may very well have been blind to this relation, due to the inherited strict distinction between science and art in modern thought. If architectural research is understood as *knowledge creation*¹³, rather than in terms of science *or* art, it is possible to bridge the unproductive separation between science and art in research and accept that it navigates multiple paradigms or systems of inquiry.

Architectural Research Paradigms

Very few attempts have been made at describing a comprehensive guide to architectural research methods, possibly owing to the relatively short history of doctoral research in architecture. In

⁹ Vitruvius. “*Architecti est scientia pluribus disciplinis et variis eruditionibus ornata, [cuius iudicio probantur omnia] quae ab ceteris artibus perficiuntur. Opera ea nascitur et fabrica et ratiocinatione.*”

¹⁰ ‘Online Etymology Dictionary’ <<http://www.etymonline.com/index.php?term=technology>> [accessed 14 April 2011].

¹¹ Silva Rhetoricae, ‘Ratiocinatio’, 2011 <<http://rhetoric.byu.edu/figures/R/ratiocinatio.htm>> [accessed 11 April 2011].

¹² Donald A. Schön, *Den Reflekterende Praktiker. Hvordan Professionelle Tænker, Når De Arbejder* (Århus: Klim, 2001).

¹³ Nonaka, 14--37.

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'*Architectural Research Methods*' Groat and Wang¹⁴ discuss the limitations of traditional dichotomies that divide research into categories of 'quantitative' or 'qualitative' research, 'hard' or 'soft' science - or even 'science' versus 'myth'.¹⁵ These dichotomies are, it is argued, overly simplistic and puts the emphasis on the level of research tactics and techniques – that is, different methods for gathering and analysing data. As a result methods are confused with research paradigms. To Groat and Wang it is important to understand research methodologies hierarchically, in terms of strategies and tactics. Research methods, which are at the level of tactics, are too often confused with research methodologies or systems of inquiry, which is the strategic level. The classic example is the distinction between qualitative and quantitative research. Instead of distinguishing research categories at the level of tactics, one should distinguish between different research paradigms which employ different systems of inquiry, Groat and Wang argue, which may again entail combinations of quantitative and qualitative research methods. As architectural research relates to bordering disciplines in which different paradigms are dominant and thus possibly has to integrate different kinds of knowledge, it becomes imperative to clarify one's paradigmatic stance as an architectural researcher. This is important, not only at the individual level, but at the institutional level too, as the assessment of research quality is likely to be judged according to the paradigmatic preferences of the assessors.

As a response to this problem, Groat and Wang proposes a 'cluster of systems of inquiry' as an integrative framework for architectural research, drawing on contributions from methodological studies in architecture and the social sciences¹⁶. The cluster integrates knowledge from three main systems of inquiry, which are termed '*postpositivist*', '*naturalistic*' and '*emancipatory*'. Each system has different ontological and epistemological assumptions, and employ different criteria in judging research quality and validity. The terminology employed by Groat and Wang is deliberately chosen in order to integrate insights from different methodological studies, where the terms may differ. By establishing a common terminology the paradigms can be more readily compared though it is noted that the comparisons should not to give preference to the postpositivist paradigm which is the oldest and consequently has a longer and more elaborated theoretical tradition than the others. The paradigms are not in a steady state, as indeed

¹⁴ Groat and Wang.

¹⁵ Groat and Wang, pp 21-43.

¹⁶ Groat and Wang, p 32. Referencing various methodologists from the social sciences: Guba & Lincoln, Mertens, Lara.

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researchers adhering to either paradigm are competing for influence, as could be seen in the so-called *Science Wars*¹⁷.

A short summary of three paradigms according to Groat and Wang¹⁸, synthesised from Mertens, Guba and Lincoln¹⁹:

Postpositivist – The traditional scientific paradigm, which assumes an objective reality existing independently of the observer. Knowledge should be acquired through ‘dispassionate’ and ‘objective’ observations, in which the researcher interferes as little as possible with the subject. A methodological preference for experimental research where results can be measured and quantified. The research assessment criteria are internal and external validity, reliability and objectivity.

Naturalistic – A more recent approach to social science: It acknowledges that knowledge and reality is constructed socially and multiple realities exist. Rather than believing in objectivity it emphasises that knowledge is reliable when backed by ‘thick’ descriptions giving it credibility and confirmability. Conclusions are transferable rather than reliable or repeatable. Qualitative research methods are used in combination with quantitative methods. The researcher is interacting with the subjects of research, and it is accepted that the researcher has tacit knowledge which is brought to bear on the study. The research does not necessarily seek to prove or disprove a hypothesis. Instead of formulating a hypothesis, the aim is rather to describe the complexities of a dilemma.

Emancipatory – Is the most recent research paradigm, and covers (as does Naturalistic) several emerging research methodologies. In emancipatory research the researcher is not objective but an active participant who not only seeks to describe the realities of a dilemma, but actively seeks to change the relations of power surrounding it. As the name implies, its validation criteria concerns

¹⁷ Science Wars refers to a heated debate among natural and social scientists which erupted after Nobel Prize Winning Physicist Alan Sokal had a nonsensical article published in a social science journal and took this as an expression of fallacy of the standards of knowledge. Nick Jardine and Marina Frasca-Spada, ‘Splendours and Miseries of the Science Wars’, 1997 <http://www.math.tohoku.ac.jp/~kuroki/Sokal/science_wars.html> [accessed 28 February 2011].

¹⁸ Groat and Wang.

¹⁹ Guba and Lincoln outline five paradigms which they note is an abstraction of several emerging systems of inquiry. Neither are the boundaries of paradigms in any way clear, as new theories are proclaimed continuously at a rapid rate of change. Egon G. Guba and Yvonna S. Lincoln, ‘Controversies, Contradictions, and Emerging Confluences’, in *The SAGE Handbook of Qualitative Research* (SAGE, 2005), pp 191-216.

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whether it establishes its historical situatedness and succeeds in eroding ignorance through a transformational impulse. The research is critical, even polemical and seeks to change reality.

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Architectural Research – Theories, Methods and Strategies

Groat and Wang distinguish between three types of theory: *positive*, *normative* and *polemical*²⁰. *Positive* theories are descriptive, causal and explanatory theories that are able to predict future behaviours of the systems they describe, developed from a disinterested position of the researcher. *Normative* theories describe value judgements related to a discipline of research, possibly to identify desired lines of actions and decisions to assist policy makers or decision takers in achieving identified often utilitarian goals. *Polemic* theories of design are theories where the theorist is actively involved in promoting a new set of values or a value system that changes the existing one. In polemical theory the theorist is involved with the subject of study from a position of power.

In addition Groat and Wang distinguish theories according to scope: Theories are described as 'small', 'medium' or 'big'. Preferably research should be relevant on the level of the research discipline of the profession surrounding it, which Groat and Wang calls the medium range of theory, as different to small theories that apply to a personal level or big worldview size theories. Theories can be brought to bear on research subjects on different levels, whether it is on the strategic or tactical level, and the theories can feed back information to the overarching philosophy framing it.

Groat and Wang identify seven research strategies: 1) Interpretative-Historical Research, 2) Qualitative Research, 3) Correlational Research, 4) Experimental and Quasi-Experimental Research, 5) Simulation and Modelling Research, 6) Logical Argumentation and 7) Case Studies and Combined Strategies.

Within these strategies a preference for certain methods may be observed, whether these are quantitative or qualitative, empirical or constructivist, and methods are presented that are typically used within the conceptual framework of each strategy. It is an important point that all these strategies are available to architectural research, all of them have strengths and weaknesses and, according to Groat and Wang, no strategy has higher intrinsic value than others. A study may even employ more strategies together, as is indicated in the Case Studies and Combined Strategies category.

²⁰ Groat and Wang, pp 78-87.

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While Groat and Wang's attempt at categorizing architectural research methods according to the notion of research paradigms establishes a frame of reference to understand architectural research in terms of recent developments in social science, it does have its blind spots. The autonomous form of knowledge in architecture which is associated with its *practice* and the influence of *art* and architecture's *media* are neglected. Groat and Wang uphold a distinction between research and design due to the difference between the generative process of designing and the analytical processes of research²¹. As architectural design draws on small scope theories such as personal experiences, emotions etc. associated with art, it is noted that this kind of knowledge is not subordinate to that of research, it is just different.²² Returning to Kwinter's position in the introduction, this distinction should not be necessary, - but why?

Towards a recognition of practice as research

In the following it will be argued that research can be understood as *knowledge creation*²³, which is a notion that highlights practice and expands the concept of research to include not only the analytical process of making tacit (practical) knowledge explicit, which is the traditional notion of research, but points to a continuous spiralling movement of knowledge between tacit and explicit states, which relies deeply on social processes. This notion is congruent with the deep history of architectural research, but remains to be clearly re-established as a valid notion of research in the wake of the dominance of the positivist paradigm of science. The recognition of the role of social processes and practice in knowledge creation is intricately connected to research in design:

Kuhn²⁴ was the first to challenge the objectivity of science, by introducing the idea of scientific paradigms that change as new theories are proposed and go through a process of accumulating acceptance before they are considered valid. This process of validation of a new paradigm or theory is essentially social, and the act of constructing theory is creative in the first instance.

Rittel and Webber²⁵ dissociated planning and social policy from the belief in positivist science which was then (1974) dominating the approaches to these disciplines. They stated that these disciplines deal with '*wicked problems*' – problems that are complex and resist resolution.

Solutions to wicked problems depend on the perception of the problem at hand, and because

²¹ Groat and Wang, p 118.

²² Groat and Wang, pp 104-107.

²³ Nonaka, 14–37.

²⁴ Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 24th ed (University of Chicago Press, 1957).

²⁵ Horst W. J. Rittel and Melvin M. Webber, 'Dilemmas in a General Theory of Planning', *Policy Sciences*, 1974, 155-169.

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intentionality is inherent in them, they are never true or false but merely better or worse, and thus elude science – in the positivist sense of the word. Wicked problems can't be resolved without leading to new problems. **Buchanan**²⁶ generalized the problematic of wicked problems to all the design disciplines, including architecture. In Buchanan's terms, as is apparently common in American design theory, design is the overarching discipline embracing sub-disciplines such as architecture, industrial design, engineering and many others that practice *design thinking*. (This position of design as the base discipline for architecture is somewhat contrary to the idea of architecture as the original profession of the master-builder or – craftsman inherited from Vitruvius²⁷, - which spawned engineering and other specialized design disciplines as specialization increased historically.) While Buchanan recognizes an element of design thinking in science, he limits that to the moment of conception when a new scientific theory is formulated. He maintains that science describes *universal properties* of the world that *is*, while design deals with the *particular properties* of a *future*. This distinction is presumably what Kwinter criticizes, when he states that science is about the creation of ideas not just facts²⁸, accepting the latent instability of ideas over time. **Schön**²⁹ outlines the way that professional knowledge is created as *reflection in action* and *reflection on action*. Reflection in action is the immediate analysis and choice of action that a practitioner in any profession takes when handling the problems inherent to his or her profession. It relates both to the practitioner's previous experience and experience of the situation, and involves a speculation on the probable outcome of the action taken. Reflection on action is a retrospective analysis of experience through discussions, note taking and evaluation. With the accumulation of experience comes professional knowledge that allows better prediction and reliability of the outcome of actions. These procedures of knowledge creation can be more or less conscious, pointing to the problem of knowledge management: How tacit knowledge is made explicit, or by its nature remains tacit either at a personal or organizational level.

Nonaka³⁰ describes how knowledge can be created and managed in organizations through a spiralling movement of knowledge conversion from tacit and explicit states. Knowledge creation requires interaction between individuals and groups with different expertises in an organization. The SECI model (Socialization, Externalization, Combination and Internalization) is a framework describing this process. *Socialization* is the conversion of tacit to tacit knowledge in which

²⁶ Richard Buchanan, 'Wicked Problems in Design Thinking', *Design Issues*, 8 (1992), 5-21 <doi:10.2307/1511637>.

²⁷ Vitruvius.

²⁸ Kwinter, p 11.

²⁹ Schön.

³⁰ Nonaka, 14–37.

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practical knowledge and skills are transferred through training. *Externalization* is the process of making tacit knowledge explicit. *Combination* is the process of combining different explicit knowledge to new knowledge, while *Internalization* is the process of learning: adapting explicit knowledge to inform the individual or organization's practical knowledge and skills. In Nonaka's view the Western tradition (of science) has "emphasized explicit knowledge"³¹. When applying Nonaka's concept of knowledge creation and the SECI model to a discussion of research that includes professional practice as a research mode, it may be argued that research is not only the externalization process making tacit knowledge explicit.

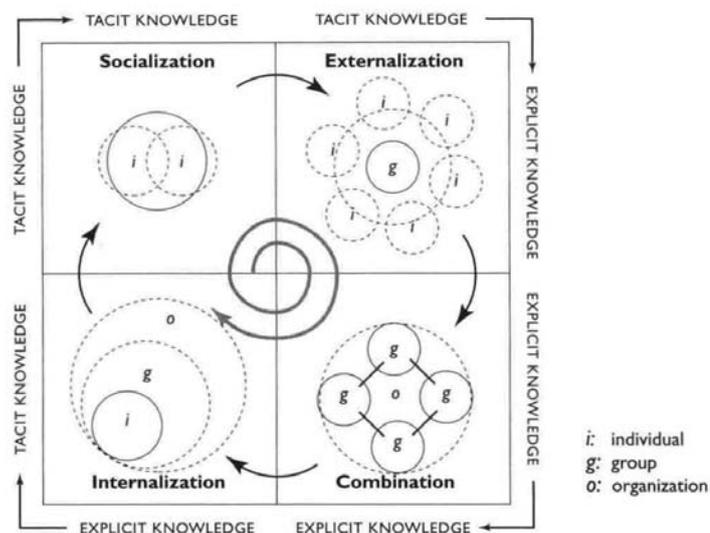


Figure 2: Spiral Evolution of Knowledge Conversion and Self-Transcending Process. Nonaka 1998

Research can be understood as the spiralling movement that moves knowledge from one state to another, regardless of whether this follows a structured or a more serendipitous approach, allowing chance insights and accepting the notion that some knowledge by nature remains tacit and resists explicitation. Nonaka highlights the use of *metaphor* and *analogue*, concepts that are traditionally associated with arts and poetic language in the western tradition, but are essential communication devices in the knowledge creation process leading to the formation of *models*³² by which Nonaka means operable, instrumental concepts. Knowledge creation is highly dependent on sharing a common conceptual and/or physical space which acknowledges differences and

³¹ Ikujiro Nonaka, 'Dr. Ikujiro Nonaka' <<http://www.entovation.com/keadmap/nonaka.htm>> [accessed 18 April 2011].

³² Ikujiro Nonaka, 'The Knowledge Creating Company', *Harvard Business Review*, 1991, 96-104.

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builds trust³³. It is fuelled by the differences among individuals and groups in the organization and depends on the intentionality, aspirations and ideals of those generating it.

Following Nonaka's lead, it may well be argued that research *always* encompasses aspects of generative and analytical thinking, and that the integration of these modes of thought are the prerequisites for innovation, which ensures the originality and possibly the relevance of the knowledge generated. The traditional hard boundaries between science, art and moral philosophy – as well as design, practice and research - can't be maintained upon closer look. Rather their identity as concepts form gravitational fields informing knowledge as it changes state with its continuous movement. It is the degree of explanatory power and generalized scope of applicability that guarantees the acceptance of theories, and their potential impacts.

While the argument for the recognition of traditional architectural theory based on polemical practice should reinforce its status as a strong field of knowledge in its own right, architecture shouldn't be content with itself. It should actively seek engagement with related disciplines as a driver for innovation and knowledge creation. Applying methods from related disciplines of thought, possibly in cross-disciplinary team-work, carries with it transformative potentials for innovation, relevance and originality. As demonstrated by Nonaka, difference is a driver for innovation, and knowledge is created by exchanges within a larger social space.

A Research Example – architecture engaging engineering

In the following a summary of the research process of the author's study Sustainability – Energy Efficiency – Daylight and Passive Solar Gains is presented. It highlights the potential of cross disciplinary teamwork to inform architectural research, by expanding the range of analysis possible and allowing technology transfer in a learning/knowledge creation process.

With little prior knowledge of sustainability, energy optimization and the physics of daylight and solar radiation, the first phase of this study followed an explorative qualitative strategy akin to grounded theory³⁴ based on data from a number of sources. To generate a dense base of information for the research and to formulate a hypothesis, data was sought using four principal strategies. 1) literature review, 2) interviews with practitioners, 3) Environmental Simulation

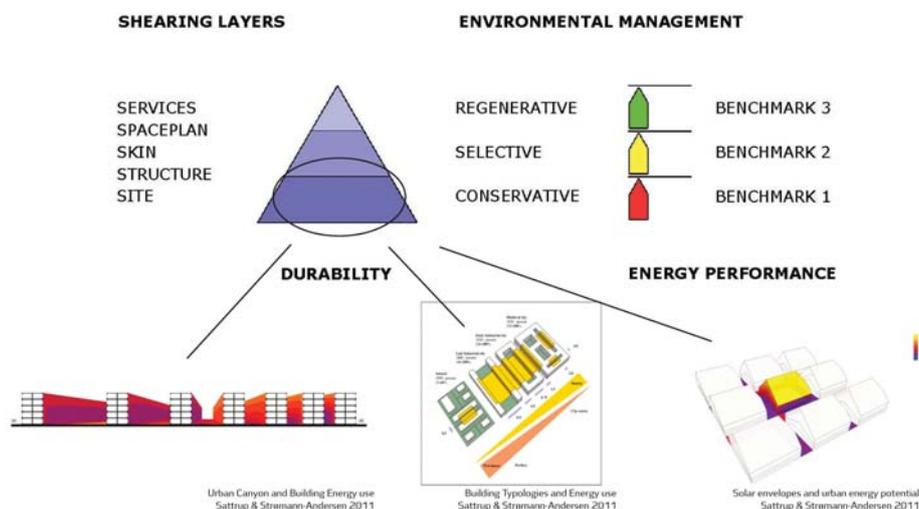
³³ Ikujiro Nonaka and Noburo Konno, 'The Concept of »Ba«:BUILDING A FOUNDATION FOR KNOWLEDGE CREATION', California Management Review, 1998 (1998), 40-54.

³⁴ Anselm C. Strauss and Juliet M. Corbin, *Basics of Qualitative Research: Second Edition: Techniques and Procedures for Developing Grounded Theory*, 2nd ed (Sage Publications, Inc, 1998), pp 1-15.

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Modelling of daylight and thermal performance of spaces, 4) observations of daylight and thermal phenomena in the built environment documenting these in memoes, photography and thermograms. Data collection using each strategy evolved more or less along parallel synchronous tracks, which allowed information to be analysed and synthesised from multiple sources. As information was condensed from these sources thematic patterns emerged that became the basis for the formulation of a hypothesis and a set of research questions.

Grounded Theory is quite different from most other scientific theories (according to some paradigmatic positions it would not be recognised as science) in that it does not seek to validate an existing theory or hypothesis through experimentation or deductive thinking, instead it seeks to develop new theory with explanatory power regarding (social) processes drawing on data and information from multiple and diverse sources. In grounded theory analysis is understood as an interplay between data and researcher, presupposing that either has influence on the other. It emphasises the process of gathering and analysing data in a structured yet creative way, allowing the researcher to consider data from many sources of information independently of media. As the data is collected it is continually coded and checked for thematic connections with data from other sources in a process where the interpretation of data shifts back and forth. Interpretations of new data may shift the interpretative attention towards previously disregarded information from datasets, which advances the process of understanding the problem at hand. The logic of creatively establishing a hypothesis follows Peirce's principle of logical abduction, in which it (contrary to deduction) is allowed to infer a cause from a consequence as a temporary position. Abduction is a prerequisite for learning, as the proposal of a hypothesis is the necessary first step to test one's assumptions of reality.



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Figure 3: Research hypothesis and three designs for testing aspects of it.

As the process of data gathering went on a hypothesis of the influence of architectural scales and layering on energy use in buildings took form, drawing on the interviews with practitioners and the literature. The hypothesis supposes that:

There is a hierarchical relationship between environmental performance and architectural scale. Design decisions taken at the biggest scales have the greatest impact.

The potential implications of the hypothesis are many as it may be applied to the design process, the operation and everyday quality of the project and its lifecycle assessment. If energy performance is used as the assessment criteria, this idea potentially connects embodied and operational energy concerns while lending itself to an incremental level of definition progress in the design process.

Though the architectural design process is not necessarily linear and design attention may shift back and forth among different scales as varying aspects of the design programme are addressed, the project and its documentation develop a high level of definition over time starting with the largest scales. Increasing the level of definition by adding details make design changes very cumbersome and expensive, and therefore it is extremely useful and important for the designer to have feedback on the basic performance of the design in the first 'rough' stages of development. Knowing which design parameters have the greatest impact on environmental performance allows the architect to navigate the many complexities of the design process with greater ease and control. But is it true? Can a hierarchy be identified? And how would it be expressed?

To test the hypothesis a range of simulation studies were designed based on architectural typologies, each with the purpose of identifying and quantifying particular environmental qualities associated with the impact of urban form on daylight, passive solar energy and building energy use.

Overall, the research process can be categorized according to three phases, which to some degree were overlapping each other in time. 'Phase' in this sense refers more to a mode of approach than

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to a period of time. As the collaboration involved engineering in which a postpositivist paradigm is more dominant than in architecture, the different phases reflect an active engagement with different paradigmatic positions.

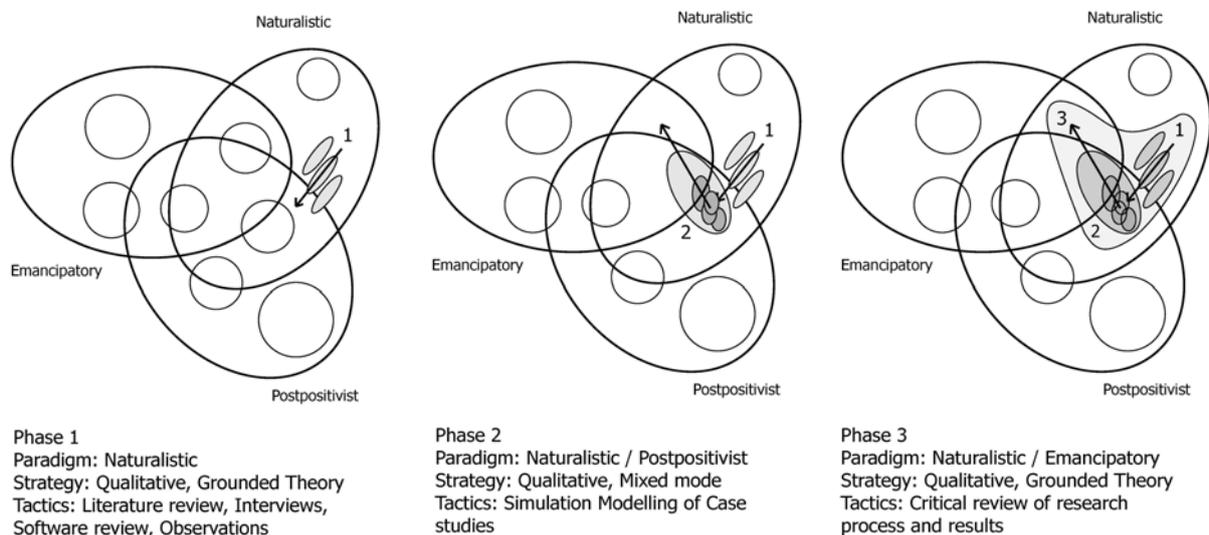


Fig 4: Paradigmatic shifts according to phases of research. Graphics based on Lara – Groat and Wang

Research process – paradigmatic shifts and creation of knowledge

In the first phase, data was gathered freely from the different sources, with the intent of creating a knowledge base of the state of the art in practice, theory and simulation technique which would be made operative in testing the hypothesis that emerged in the process. The paradigmatic stance of this phase was naturalistic in nature, ontologically presupposing an objective reality subject to individual and social interpretation and negotiation, while epistemologically following a critical approach to practice, theory and simulation modelling techniques.

In the second phase, the qualitative approach encountered an inherently (post)positivist paradigmatic stance as three different aspects of urban form and materiality were investigated in close collaboration with engineering doctoral student Jakob Strømmand-Andersen. Studying the energy performance of buildings in dense urban contexts each researcher attempted to understand the other's disciplinary research methodology, concerns and techniques.

In the third phase, the experience gathered in the first two phases is discussed critically. A theoretical framework emerged by the end of the simulation studies that facilitates a discussion of simulation modelling as a generative tool in architecture as opposed to its use for validation in

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engineering, centering the focus for optimization on the user of the building and the experience of space. The limitations of simulation modelling applying a reductivist deterministic approach to building performance is highlighted in favour of a mixed natural and social sciences approach where architecture as an applied art and science forms its integrative core.

Cross-disciplinary collaboration – expanding the borders of each discipline

The collaboration in Phase two requires some further explanation: The interviews and the research into the state of the art of simulation software had also made it clear that it would be necessary to use emergent software in order to be able to push the boundaries of knowledge significantly. As I did not have the necessary technical expertise personally, neither was it available in the immediate or remote academic environment, it had to be developed. As the most promising pieces of software for these purposes were developed mainly for engineers and had very limited functionalities directly applicable to architectural design, I judged it promising, if not necessary, to engage in a cross-disciplinary collaboration with civil engineering PhD student Jakob Strømmand-Andersen, so as to be able to explore the potentials of the software. As better integration of technical performance is demanded by design practices, this research collaboration could very well be understood as integrated design research.

The starting point was a research design covering many architectural scales proposed by myself so as to see if any hierarchy could be observed, by way of analysing the environmental and energy performance of selected architectural typologies, which were simulated by my collaborator Jakob. By collaborating closely through several iterations of studies, tacit and explicit knowledge from either discipline was transferred among either of us, and a common understanding of technical and design considerations emerged. As mutual understanding grew, it became increasingly difficult to distinguish individual conceptual contributions from those arrived at in common.

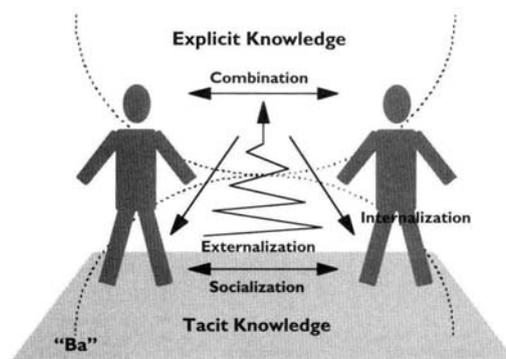


Figure 5: “Ba” (shared space) and Knowledge creation, Nonaka 1998

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Nonaka's SECI model offers an explanatory model for understanding the process: The first phase's literature review is a process of *combination* and *internalization* as theoretical knowledge is slowly grafted into new hypothesis and research questions, the interviews with practitioners inform the research by explicitation of tacit knowledge from practice by *externalization* and *combination* of the different positions encountered. By collaborating in the second phase tacit and explicit knowledge was transferred in reciprocal movements between the two disciplinary approaches to environmental simulation through *socialization*, *internalization*, *externalization* and *combination*. As a result contributions to both architecture and engineering knowledge were achieved. The critical discussion of Phase three may inform future knowledge creation as it becomes accepted socially by the profession and integrated in the discipline.

Conclusions

New paradigms of research are beginning to recognize the validity and value of what architectural theory has done for millennia, which is the polemical production of alternative modes of thinking, living and creating environments by model or built exemplar. The recognition of practice as inseparable from research reaffirms the identity of architectural research that builds on experience and creates new realities.

Architecture relies on its media of representation and fabrication in order to communicate its agency on multiple levels of reality. As architectural research and theory can't be dissociated from architectural practice, doctoral education should recognize the inherent importance of architecture's media and prepare the students for specialization and collaboration at the borders of the discipline.

It is argued that the nature of architecture as a research discipline is essentially integrative and generative, and that the basic education of doctoral students in architecture should have a polyhistoric approach to reflect that, preparing the students to navigate the different research paradigms surrounding the discipline. A variety of methods from the social and natural sciences, philosophy and technology may serve to expand the borders of architectural knowledge.

Certainly, architects should be able to write / draw / build a PhD, - but it is in the application of multiple media and varied methods that architectural research best demonstrates its integrative and generative potential and consequently its value to society.

Architectural Research Paradigms – an overview and a research example

Research Phase	Phase 1	Phase 2	Phase 3
Paradigm	Naturalist	Naturalist (Postpositivist)	Naturalist (Emancipatory)
Ontology	"Multiple, socially constructed realities"	"Multiple, socially constructed realities" investigating the "One reality; knowable within probability" notion	"Multiple realities shaped by social, political, cultural, economic values"
Epistemology	"Interactive link between researcher and participants; values are made explicit; created findings"	"Objectivity is important; researcher manipulates and observes in dispassionate, objective manner"	"Interactive link between researcher and participants; knowledge is socially and historically situated"
Hypothesis	<i>Under development, assuming that environmental simulation may be instrumental to improve sustainability through energy performance for daylight and thermal comfort</i>	<i>Urban density and Building Energy use are hierarchically dependent. The urban geometries surrounding and regulating a building's site have major influence on that building's energy performance over its lifetime.</i>	<i>The use of environmental simulation tools will change architectural culture, as new techniques offer improved control of design performance</i>
Research question	<i>What is the state of the art of architectural practice, theory and environmental simulation technology regarding energy performance?</i>	<i>How does urban form relate to building energy, daylight and thermal performance in the context of Copenhagen?</i>	<i>How may environmental simulation change architectural culture?</i>
Methodology	qualitative research: grounded theory, modified	Qualitative research framing a Mixed Mode Case Studies through - Simulation and Modelling	Critical discussion
Strategy	Collection of data from multiple sources to produce hypothesis: - Architectural and engineering practice - Theory, - Environmental Simulation tools	qualitative discussion of environmental simulation results.	Argumentation and critique based on observations and experience 'grounded theory' from phase 1 & 2
Tactics	- Literature review - Interviews - Observations of climatic, cultural, physical behavioral phenomena - Review of simulation software types	Environmental Simulation Modelling experiments.	Critical discussion of research process
Notational media	written language photography thermography diagrams	written language, digital environmental simulation modelling diagrams	written language diagrams
Interpretative logic	abductive hermeneutic	inductive / deductive hermeneutic	abductive hermeneutic critical

Figure 4: Framework showing paradigmatic shifts in the research process

Architectural Research Paradigms – an overview and a research example

Empirical matter / object of interpretation	State of Art: Practice Theory Technology	Digital models of generic urban environments: - urban canyon - urban pattern - urban envelope	research process: phase 1 and 2
Research Aims	understand	understand, control and predict	understand critique and change
Position of Researcher	Independent Participant	Independent	Participatory
Type of Theory	descriptive	descriptive / normative	descriptive / critical
Research assessment criteria	Credibility Transferability Dependability Confirmability	Credibility Transferability Dependability Confirmability Internal/external validity reliability objectivity	Credibility Transferability Dependability Confirmability Historic situatedness Eroding Ignorance Transformational impulse
Theoretical scope S,M,L,XL	S & M: from personal experience to professional boundaries	S & M: from personal experience to professional boundaries	S,M & L: from personal experience to professional boundaries and societal values
Conclusions (or, - following the logic of naturalist inquiry: 'tentative generalised claims' (Robertson 2008)	Experienced practitioners are using and developing environmental simulation tools to control energy performance of their projects. Both Eberle and Foster's office report a hierarchy of scale influencing energy demand and environmental impact. Emerging practices show ways to express environmental concerns that have previously been only theoretically described. Rich sources of theory on environmental performance has remained unattended in main stream architecture	There are some hierarchical relations between scales, but they change in dynamic ways when single parameters are varied. Urban geometries have significant impact on energy performance, but affect in particular the experiential qualities Rhythms of use and changing intensities of energy potentials form a complex climatic/social spatio/temporal context for architects to consider in order to achieve desired environmental performance relying on a minimum of operational energy use.	Environmental simulation offers control of new scales of energy in architecture: Intensity and Duration. To improve creative and qualitative aspects of the built environment, architects need to inform structure and control of energy performance. The regulative framework guiding urban form in relation to energy performance of buildings in Denmark is simplistic and outdated. Integrated methods of quantitative and qualitative assessment to achieve environmental diversity in future developments.
Sources: Munk 2010, Lincoln & Guba 2005, Groat & Wang 2001, Robertson 2008	Architectural theory describes environmental performance in a variety of ways that are not necessarily quantifiable per se, but could be brought to bear on the way environmental performance is quantified and determined in engineering	Visualization and environmental simulation can aid architects in conceptualizing and achieving desired environmental performance, aiding architects in controlling the qualitative and some of the quantitative aspects of energy performance	Environmental simulation tools can be understood as extensions to our senses and intellects rather than sophisticated calculators. Using simulation to train perception and analysis can allow architects to creatively challenge the 'comfort zone' thinking

Figure 5: Framework showing paradigmatic shifts in the research process