



The Quest for Innovation: Methods and Mindsets

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Abstract

Innovation in the building industry has been lagging behind other fields, due in part to the fragmented nature of the field of construction, but also due to the lack of research methods that can effectively merge scientific and creative methods into a single approach. The paper discussed a novel method for interdisciplinary work at the intersection of computation, architectural design, engineering and material science. The approach was developed in the Material Processes and Systems Group at the Graduate School of Design at Harvard University.

Keywords:

Interdisciplinary Work, Design Research, Scientific Research, Research Methods, Material Systems, Design Thinking

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INTRODUCTION

If airplanes were like buildings we would still be going around in biplanes. A comparison of the rate of progress and advancement in the building industry with that in the field of aerospace engineering can lead to no other conclusion. Humans have constructed shelters from the very beginning of human existence many thousands of years ago, but even today's most advanced buildings have ultimately advanced very little. Bricks today have the same shape as the very first human made unfired clay bricks about 6000 years ago. Glass today is only marginally better than glazing systems in the middle-ages. Structural efficiency in wood construction, for example, has only increased by a factor of an estimated 3 or 4 over 2000 years. Drafting a similar comparison with human flight we find a much accelerated development from Otto Lilienthal's work and the Wright brother's first motorized flight in 1903. Now, just over 110 years later, airplanes carry hundreds of people, fly faster than the speed of sound, and last decades in continuous service. What went wrong with architecture?

The well-known fragmentation of the building industry usually is first blamed for the snail-pace of progress in our field. Compared to that relatively few companies, and solid government support, has propelled the aerospace industry forward. The World Wars with their military needs triggered an intense research phase that fast-forwarded airplane design and engineering, and without which the aerospace industry would not be where it is today. Wars have contributed little if anything to building design, instead drawing resources away from any serious building-related research effort. But don't our buildings, after all, perform reasonably well as they are? Even buildings constructed hundreds of years ago are fairly safe and moderately comfortable. Why invest much towards innovation in the construction sector?

Today we know this presumption to be utterly wrong. The relative inefficiency of constructing and operating our buildings consumes the majority of global raw materials and energy, and contributes a large amount of emissions to our rapidly warming planet. Building design and construction has to rapidly catch up and become vastly smarter, leaner, and more sustainable. But to advance our industry we need new ideas and methods in order to accelerate the rate of innovation. We cannot wait hundreds of years to lower carbon efficiency of our existing and our new buildings. We can no longer afford to postpone progress. We need to re-tool our discipline, and emphasize research!

RESEARCH IN ARCHITECTURE?

Individuals without connections to the building industry are often surprised to hear that research indeed exists in our field. What one could possibly be working on is equally unclear to outsiders, much in contrast to fields such as engineering or medicine where research is widely assumed to be fundamental. There is more understanding of building related research in the University setting, where colleagues from other disciplines expect those affiliate with departments of architecture, landscape architecture or urban design and planning to be scholarly engaged.

At Harvard University I am engaged with a broad range of research projects and topics, most of which are connected through their pursuit of material systems and innovation. Conducted in the context of the Material Processes and Systems (MaPS) group, and often collaborating with Prof. Sayegh's Responsive Environments and Artifacts (REAL) group, our work is different from yet related to material science, refers to industrial process engineering as much as to chemistry and building physics. It operates on dramatically different scales, from the nano-scale to the scale of the city, with outcomes that range from prototypes and pilot project to patents and papers. Most importantly, however, the work has led to the development of methods that accelerate the rate of innovation and our quest for novelty, ultimately geared towards advancing the built environment to a more sustainable future. This article puts forward several aspects of this work in a provocative, polemical manner as food for thought, not as a literal recipe for success.

MaPS Design Research

Material systems describes a broad interest in all aspects of materiality, beginning with extraction and sourcing, through processing and fabrication, transportation and distribution to construction, use and finally end-of life scenarios of reuse, recycling, or disposal. The work includes studies for the intermediate as well as those for an immediate future, some is more, other less driven by applications, and all of the work is collaborative often across disciplinary divides. The following aspects have evolved over several years of working on different topics and problems. They will be illustrated with examples from a variety of past and present research projects.

Briefs not Plans: Traditional research often crafts a precise research plan at the outset. Doing so works well if the problems, methods and goals are articulated and well understood, but it can be limiting when innovating in the materials area and dealing with the uncertainty of unknown application domains.

Figure 1. Robotically waterjet, stone slabs were manipulated such that 72 perforated thin stone slabs, precisely cut, could be dry-assembled into a loadbearing and post-tensioned shell.

Here the commitment to a theme can be a more productive way to guide the imagination and channel thought processes towards novel outcomes. These themes are often described in the form of briefs – a tradition long established in the studio model of design education where professors challenge their students with a brief that includes programmatic and other requirements for a building. In the research setting briefs can be less quantitatively specific, but instead often focus on themes that are aligned with real world issues and the capabilities of the research team.

The Surfacing Stone project illustrates this principle well. Here several Harvard faculty¹ and students formed a group to investigate and discover new design opportunities brought about by manipulating natural stone with a 6 axis robotic waterjet. The team developed a thematic brief that focused on the manipulation of stone with the goal of controlling light transmission and views in ways that were unique to both the tool as well as the material. This quest ultimately resulted in a novel structural stone shell robotically cut and perforated to address views during the approach to the site of the installation (Figure 1).



(1) Faculty included Monica Ponce de Leon, Wes McGee and the author.

Questions not Answers: A good interview relies as much on good answers as it depends on the right questions. Questions are essential in research as well, because the research can be looked at as an answer to questions. Coming up with good questions is not always easy, but in itself requires research.

In our ongoing interdisciplinary work with chemists and material scientists the value of questions has become evident. During an initial meeting our partners asked a seemingly simple question: what work could the scientists that would solve the most pressing problems of buildings today? While not in itself a bad question it did not allow us to formulate a research agenda. The vast scale difference between the built environment and material science makes the question of what research can connect those fields in itself intriguing and non-obvious. In addition to this material science in itself is a vast field, but one characterized by researchers and labs with extremely specific expertise and interests. Our challenge over several months of meetings and conversations was to find an entry point with the

promise to match the capabilities of our scientific partners with a promising application domain in the built environment. We eventually were able to collaborate together by starting with a range of translucent material systems that allowed us to investigate questions of views and light control, among others. This work continues and grows today, involving several faculty from the Harvard Graduate School of Design (GSD) and the Harvard School of Engineering and Applied Science (SEAS)², and today is conducted under the Adaptive Living Environments (ALivE) umbrella (Figure 2).

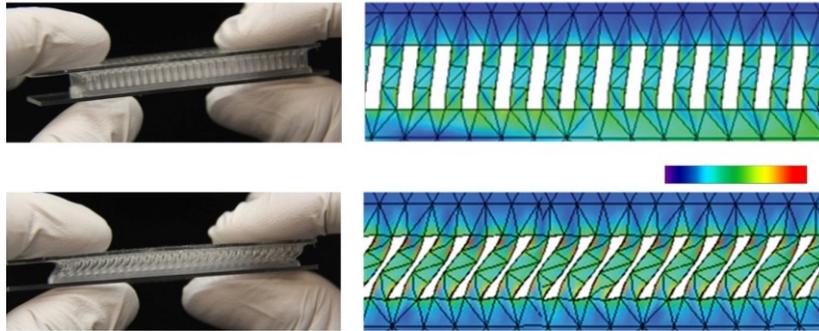


Figure 2. The patented Dynamic Daylight Control System, a joint development of designers and scientists, relies on the shearing of soft pneumatic layers to control daylight³.

(2) Key faculty are Allen Sayegh (Co-PI) and Panagiotis Michalatos, both GSD, and Joanna Aizenberg and Katia Bertoldi both from SEAS and the Wyss Institute of Biologically Inspired Engineering.

Many not Few: There are very few geniuses among us, but together we can create novelty and, through implementation, also innovation. Collaboration as a principle of scientific and creative work, of course, has a long tradition. MaPS work is always collaborative, but for certain projects we amplify the potential of many minds over fewer by inviting guests without prior knowledge of our work to brainstorm with us to generate ideas. This process involves the creation of an appropriate spatial setting and the definition of themes and challenges that participants address in small groups. We intentionally mix individuals from different disciplines because we value diverse input.

Brainstorming sessions have created several intriguing new ideas in the context of the ALivE project, where the challenge in the early research phase is to identify real opportunities for innovation in the built environment based on the given nano-scale material science expertise of our collaborators. We mix scientists, designers, artists and others in small groups that come up with ideas in joint conversation that is moderated by one of the group members. Moderators are not determined based on hierarchy, but by their ability to keep a conversation going and stay focused on a theme. Every group is challenged to come up with 5 – 10 ideas within a very short time. All ideas are presented both graphically as well as textually, and at the end of a brainstorming session the ideas are shared. All participants then ‘vote’ on what they perceive are the best ideas. This vote helps the core team understand better what ideas may point to

(3) Park, D., Kim, P. Alvarenga, J., Jin, K., Aizenberg, J., Bechthold, M.: “Dynamic daylight control system implementing thin cast arrays of polydimethylsiloxane-based millimeter-scale transparent louvers” in: Building and Environment, 2014.



Figure 3. ALivE ideation or brainstorming sessions develop many ideas which are later analyzed and categorized in order to decide what to work on.

real opportunities, hence are worthwhile investing time and resources in for further development. Following the brainstorming session we further analyze all ideas, cluster and sort them by categories such as application domains, effect, or underlying technology, and proceed from there jointly with our scientific partners with the research (Figure 3).

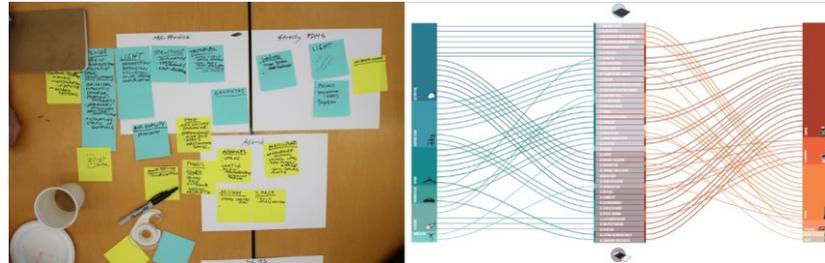


Figure 4. ALivE exhibitions generate discussions, feedback, and ultimately advance the development process.

Another aspect of this principle is to share our in-progress work with broader audiences. In the ALivE project we create an exhibition once to twice a year, and invite Harvard affiliates as well as outsiders to visit the shows and share their reactions with us. This process, although time consuming, again provides valuable feedback to us and helps us steer the development process of the various projects we are working on (Figure 4).



Get Physical: The principle of productive failure or ‘failing early’ is well known in product design circles⁴, and it refers to the importance of trying out ideas physically because the development process will benefit as much from what does not work as it gains from what works. This is certainly true for our work on ceramic material systems where prototypes are an essential part of the development process (Figure 5). It is also true for our collaboration with material scientists. Here the degree to which prototypes and their failures can be productive correlates strongly with the physical scale of the experiment.



Figure 5. Prototyping at different levels of precision was key in developing a novel ceramic structure⁵.

In the ALivE work it is essential to prototype ideas early. Other than in product design where basic ideas can often be prototypes with basic materials such as tape, cardboard and other available resources any scientific study requires much more time and effort in order to work. Prototypes need to be carefully planned and designed. Material science usually produces very small experiments, and declares success if certain behaviors or effects can be demonstrated at the nano- or the micro scale. Functionality of the larger scale is then inferred. We often begin our work with scientists at the point where certain material behaviors have been successfully demonstrated. In our quest for applications ALivE students and researchers then design objects that are situated in between models and products, in between material samples and experiments. These objects often strive to demonstrate a novel relationship between an environmental stimulus and one or more human senses. They remain fairly small – can be produced in scientific labs geared towards succeeding on the small scale – yet are large enough to help us evaluate their behavior through direct personal experience rather than through the intermediate interface of scientific instruments.

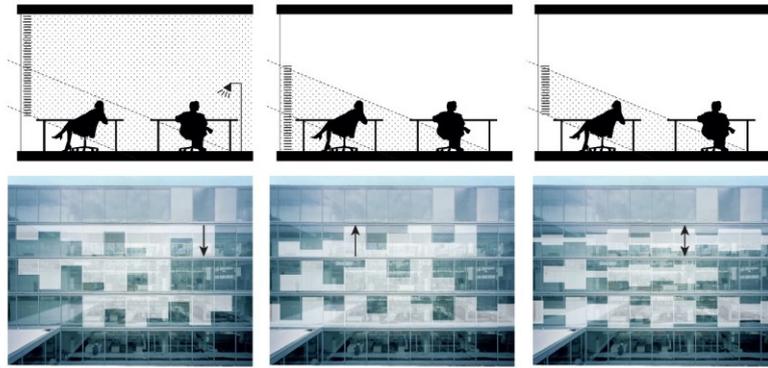
Suspend Doubt: Work in both the sciences and in the field of design is often guided by a hypothesis, but designers will rarely think of their proposals as such. But design as the transformation of an undesirable into a desirable condition⁶ always contains an element of hypothesis or conjecture. Compared to scientific work the scenarios generated by designers can often seem bold, far-fetched, or lacking rigor. Designers can give form to future scenarios and environments, to settings and processes that might be enabled by something the relevant scientific research has only begun to understand. These visions have not overlooked, but they intentionally suspend doubt about the many practical and research problems that need to be solved before a vision turns into reality. Design visions provide guidance and motivation at the same time (Figure 6).

(4) Brown, T., Roberts, T.: *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation*. New York: Harper Business, 2009.

(5) The project was developed in collaboration with Prof. Andreas Trummer from the TU Graz. The author thanks ASCER Tile of Spain for their support.

Figure 6. Before the actual development of the DDSC system shown in figure 2 the team crafted a vision sketching out the experience of a building's occupant as well as possibly adaptive appearances of a building. At that stage multiple technical problems still had to be worked out before these visions could become reality.

(6) Paraphrasing Herbert Simon.



Top and Bottom: Design research excels through the ability to switch from top down to bottom up thinking. These terms describe attitudes during the development process describes. Top down denotes an application, problem-centered viewpoint while bottom up is the development of capabilities starting with material experiments or other fundamental science. Both perspectives are needed, both require the suspension of doubt as mentioned before. Innovation can emerge if researchers are able to switch modes easily and at the right times.

CONCLUSIONS

Architecture and the building industry needs to advance. To do so we not only need more substantial industry and government commitment, but also methods that allow designers to productively advance novel ideas in collaboration with other fields such as material science, chemistry or engineering, to just name a few. Leadership during this process is the ability of designing and guiding the process itself such that innovative outcomes emerge. The principles outlined above can form integral part of this new approach to interdisciplinary research. Design methods that originate in architectural thinking are not limited to the conception of buildings, but they can be instrumental in crafting successful interdisciplinary collaborations that are able to address the challenges of our time.

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RESUME

Bechthold is co-director of the Doctor of Design Program and director of the GSD's Technology Platform. He teaches courses in design robotics and material systems, building structures, as well as lifecycle design. Recent courses include CeramicsLab, the TRACES option studio, Analysis and Design of Building Structures I and II, as well as Computer-Aided Design and Manufacturing (Cad/Cam).

Bechthold received a Diplom-Ingenieur degree in architecture from the Rheinisch-Westfälische Technische Hochschule in Aachen, Germany, and a Doctor of Design Degree from the Graduate School of Design at Harvard University. He is a registered architect in Germany and has practiced in London, Paris, and Hamburg. During this period he was associated with firms such as Skidmore, Owings & Merrill, Santiago Calatrava and von Gerkan, Marg & Partner.

Bechthold's research broadly looks at material and fabrication technology as a catalyst of innovation for design practice. In 2010 he founded the GSD's Design Robotics Group (DRG), a group of faculty, research associates and students that pursues sponsored and other research projects. DRG's current research focuses on integrating robotic technology into fabrication and construction processes, developing advanced material systems in collaboration with industry partners and the Wyss Institute for Biologically Inspired Engineering at Harvard University, and understanding problems of lifecycle design in (building) products. Bechthold is co-author of "Structures" and "Computer-Aided Design and Manufacturing" as well as the author of "Innovative Surface Structures".