

PROTOTYPES IN ARCHITECTURAL EDUCATION: AS INSTRUMENTS OF INTEGRATION IN THE DIGITAL ERA

Fulya ÖZSEL AKİPEK and Nilüfer KOZİKOĞLU

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1. Kepes' aim was always more than just producing novel art forms; he wanted art to promote a more expansive sense of connectedness among separated communities and to foster a more holistic awareness of the world as a complex ecological system (Kepes, 1968).

Architectural design and education today has a strong new focus on process, material and data organizations with the conceptual background of emergence and complexity of the digital era. In this paper, we reevaluate the design as research, and distinguish the digital and conceptual modes of prototypes in dialogue with the material prototypes. Through four instances in our current educational experience, we review this dialogue and the field of potentialities that exist in the interrelation of the different modes of prototypes. Contemporary design entails relational thinking, computational and systemic methodology and thus operates within the continuous feedback between the digital and the material.

DESIGN AS RESEARCH

Thinking of the design domain in the context of ideas and technology of its day is essential to grasp its changing dynamics. For examples of *design as research*, we look into the works of Kepes, da Vinci, Gaudi, Otto and Koman, who experimented with series of novel techniques. Their work has enhanced design knowledge and is not limited to only one specific domain.

In all areas of design, research is found in the form of experimentation and technology-sharing, as the way to integrate design knowledge to the concepts of its time. Gyorgy Kepes, founder of the Centre for Advanced Visual Studies (CAVS) at MIT, dedicated it to creative collaboration between artists and scientists. For years, researchers at CAVS have pioneered the use of technologies such as lasers, plasma sculptures, sky art and holography as tools of expression in public and environmental art. The work in these studios, together with his own work, relied on experiments that are posed between art and design (**Figure 1**)(1).



Figure 1. High speed photography by Gyorgy Kepes, 1978. (Supovitz, M., Kepes, G., *Gyorgy Kepes, the MIT years, 1945-1977*, The MIT Press; New Ed edition, 1978)

Da Vinci's holistic approach to design in 1500s directs research towards various realms; human and animal anatomy, natural phenomena such as branching of trees, water flows, flying of birds, sound waves and music

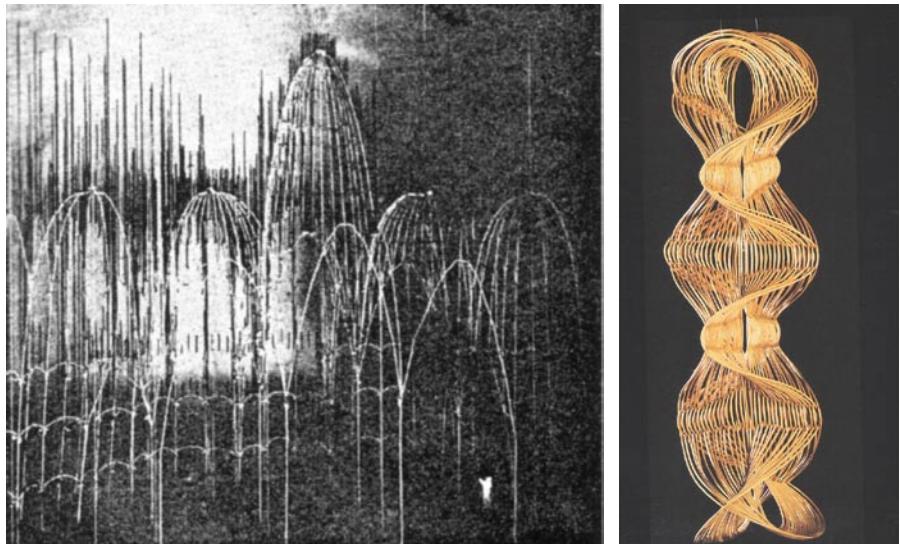


Figure 2. Chain modelling techniques of Gaudi. (Huerta, 2006; 324-39).

Figure 3. Untitled wood piece from Koman in Stockholm. (İlhan Koman Retrospektif, Exhibition catalogue, YKY, May 2005, İstanbul).

(White, 2000). All the information acquired through experimentation in these diverse fields feed one another to improve design knowledge. Da Vinci's approach, scientific as much as artistic, is an example of continuing discussions on the position of design between art and science; where research and interaction are key factors to bridge the gap.

Gaudi's experiments with hanging models made of chains, and other materials, aim to reveal forces by transformation (Huerta, 2006). Frei Otto's operations with wool water techniques, experiments with rubber-like material like soap bubbles or textile, are samples of research in the mode of *analogue computing*, forming resources for design research in the digital era (Kolarevic and Malkawi, 2005) (Figure 2, 3).

İlhan Koman, a sculptor of the 1970s, calls his research "embryonic" in the sense that each piece embodies new ideas and the need for a different know-how that could be exploited in making further works of the same type. He has dealt with evolving concepts of geometry and mathematics, such as non-rigid polyhedral or topological forms, and has worked with prototypes especially out of materials such as iron and wood. He has used inherent characteristics of these materials, e.g. the flexibility of wood in his kinetic sculptures (Koman, Ribeyrolles, 1979). In the works of Koman and his special interest on mathematics, geometry, motion and time and relating these concepts to the substance of materials, what interests us is his attitude of taking each concept as a design research subject and treating his art pieces as prototypes.

2. With the reflections of integrated or relational approaches in the current era, such as Bateson's approach in adopting ecological principles (recursive feedback, information patterns, network and individual flexibility/organization, etc.) to the discussion of anthropology, psychology (with particular emphasis on an ecosystem model of the mind), and epistemology, architectural domain adopts notions of time and movement, complexity, nonlinearity and emergence as the conceptual, and operational forces in design, with a focus on the computational basis (Bateson, 1972).

The integrated or relational approaches of these precedents as well as others in our current era, such as Bateson's approach in adopting ecological principles (2), along with the advances in information technologies, open up a new research platform which calls for a new kind of design research approach in architecture. Most of these issues were subjects of design in various times as mentioned in the works of artists, scientists, or architects mentioned above, and the current era also has its new toolsets and methods of digital environment for research.

Design research (DR) domain, origin in the 1960s, has long been searching methods to take design as a discipline of its own, with its own ways of research and communication, aiming to promote research in the process of designing in all its many fields (Cross, 2007).

Cross defines the three thresholds in the evolution of design research, starting with *design science approach* which tries to relate design methods with scientific methods, that “implies an explicitly organised, rational and wholly systematic approach to design, design in some sense a scientific activity itself”. The second epoch is that of *science of design*, which makes clear that design as an activity is not wholly scientific but can be investigated with scientific methods. After 1980s suggestions taking *design as a discipline* were seen, “design studied in its own terms, within its rigorous culture to construct a way of conversing about design that is at the same time both interdisciplinary and disciplined”.

In response to the above description of DR, design research approach in architecture can be defined as an attitude which is characterised by taking *design activity out of the boundaries* of the domain of architecture, and relating it with all other fields of design such as industrial design, mechanical design, urban planning, engineering, textile design etc. In the definitions of Cross, we find design in a distant standpoint to art, evaluated more with its relations to science. Relations and interactions with other design fields as well as art, thinking with their modes of thought and their toolsets is an open-source for creativity as well as information. The nature of design research entails focus on *design as a process* rather than taking design as a problem-solving activity and challenges experimenting methods which is also the state of art in architecture.

In the current state of architectural education, there are integrated models with DR approach, such as AADRL which operates in a collaborative learning environment, or units organised to work as design research laboratories as RMIT-SIAL (Spatial Information Architecture Laboratory) that investigates the culture and practice of contemporary creative production, and research based groups in architectural faculties such as Columbia-CONTINUUM, intersecting interests between academia, corporate, practice and industry to create design tools. DR is also the attitude in some individual works in praxis, as decoi, Servo, Objectile or NOX, working in collaboration with education. *Design as a form of research and research based education* seems to be the key concepts to take DR approach within architectural design education as Height and Perry emphasize (Height and Perry, 2006).

PROTOTYPES IN ARCHITECTURE: INTERACTIONS IN-BETWEEN MATERIAL, CONCEPTUAL AND DIGITAL PROTOTYPES

Common use of “prototype” refers to industrial design and engineering field models that serve specific proof-based objectives. Ullman (2003) describes four classes of prototypes based on their function and stage in product development:

- To better understand what approach to take in designing a product, *a proof-of-concept prototype* is used in the initial stages of design.
- Later, a *proof-of-product prototype* clarifies a design’s physical embodiment and production feasibility.
- A *proof-of-process prototype* shows that the production methods and materials can successfully end up in the desired product.
- Finally, a *proof-of-production prototype* demonstrates that the complete manufacturing process is effective.

Within the current thinking, which does not distinguish the product from its design and creates a strong focus on process, prototypes, rather than the proofs, become the tools of design research. Prototypes are actualized instances in the generative process. With this point of view, prototypes cause feed back and interaction, and are parametricly setup and operational, in order to serve as instruments in design.

The digital medium, latent with novel modes of investigation, entails a relational thinking in between material, conceptual and digital modes of operation. Here, we distinguish three kinds of prototypes as basic instruments for an integrated design education in architecture: Material, conceptual and digital prototypes. **Material prototype** in design development is in the tactile mode, that is, in actual physical setting. Performing as a whole while testing components, it is instrumental in the search for coherence of the subsidiary parameters with the context. This is a systemic approach where space and structure are correlated. The abstract mode of prototype is the **conceptual prototype** that works on a diagrammatic base, entailing a relational system of data organization, operates in a virtual mode but can also be physically constructed. **Digital prototypes** are parametric computational models constructed in a coded media, keeping the material and conceptual data inert interrelational within its digital components.

Material Prototypes

The material prototype is a tactile instance of structural composition that reveals the potentials of space and performance. There is a systematic material organisation with focus on operations and techniques that serve to analyse and design a set of relations, generates a catalogue rather than a singularity. The focus is on the behaviour of the whole, the complex system, as well as the inert potentialities of the material in the morphogenesis process. Factors involved in the genesis of form are already found in the properties of the material (3).

These analogue models serve to create the critical interaction with the physical phenomena; that is both intrinsic forces as well as external ones like gravity, light and movement. Products are usually 1-1 or as close to the exact behaviour or range that fits in the true context. Therefore, these are not mere product tests or mock-ups but instruments for designing the generative process.

Pavilions, in the past and today, have been prototypes for concurrent novel concepts, materials, techniques and technologies. In parallel, material prototypes in design process are system samples, in the feed-back of the creative cycle, even in the case of unpredicted results, rather than testing the issues of the product.

Precedents of the use of material prototypes in education can be traced back to the Bauhaus. Trade with speed, movement, abstraction, brings craft, art and technology into the design education realm and makes use of prototypes in the process. The basic learning places of architecture in the Bauhaus were the *ateliers*, places of investigation and experimentation on different materials like wood, metal, textile and novel design techniques. Although the material prototypes in the Bauhaus were test pieces for mass production, they were also instrumental in dealing and designing the concepts of the era. Laboratory for producing the speculative experiments is the place of education and the experimenter is the designer-student (4).

3. "Resources involved in the genesis of form are immanent to matter itself." (De Landa, 2004)

4. "The models and prototypes that will then go into production in the factory will be tests in speculative experiments in the laboratories of Bauhaus." (Conrads, 1975)

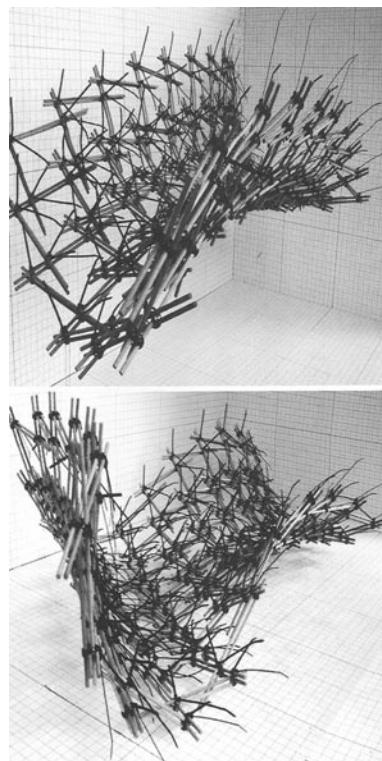


Figure 4. A Material Prototype, Discontinuous strut lattices. (Michael Hensel and Achim Menges, eds. (2006) *Morphoeologies: AA Dip 4 Morph Ecologies*, Architectural Association.

Contemporary design education in architecture benefits from material prototypes with the new CAD/CAM toolsets. Potentials of these new toolsets are their parametric set up and computational lay-out, which enhance the operational quality of the prototype (**Figure 4**).

Conceptual Prototypes

The conceptual prototype is a diagram that constitutes the setting out of the interplay of forces in 'pure matter-function' (5). The form of an object is a "diagram of forces"; in this sense, we can judge or deduce the forces that are acting or have acted upon it. This generative diagram is the reconstruction of the datasets and the relations abstracted from the nontactile variables in design (**Figure 5, 6**).

In previous attempts in education, *Texas Rangers* emerge as the avant-gardes for the use of conceptual prototypes. They have turned the educational perspective from material to a conceptual or a more abstract one. Context, program and structure have become the substance of design and education through the process based methodologies (Hejduk, 1988). These methodologies and exercises like the nine-square-grid are prototypical, not in the same sense as the physical prototypes of the Bauhaus, but as conceptual prototypes which create some knowledge of form making.

Architectural education today recredits diagrams and diagrammatic exercises in the digital era. Apart from advanced visualisations, the major impact is on the decoding and mapping of various kinds of data. This computational medium reveals pattern organizations as the operative infrastructure for resolving the relations in design and production; not as the intuitive abstract concept schemes as it was before.

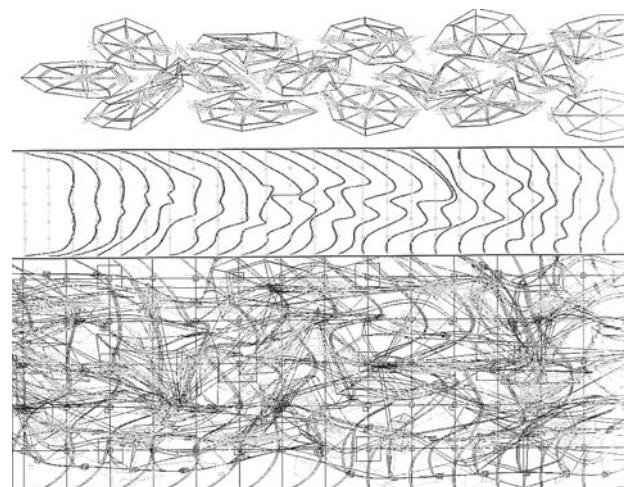


Figure 5. A Conceptual Prototype, Nona Yehia, Tokyo bay free zone. (Bernard Tschumi and M. Berman (2003) *Index architecture: a Columbia book of architecture*, MIT Press, Cambridge, MA.; 6a).



Figure 6. A Conceptual Prototype (Paul Klee (1968) *Pedagogical Sketchbook*, Faber and Faber).

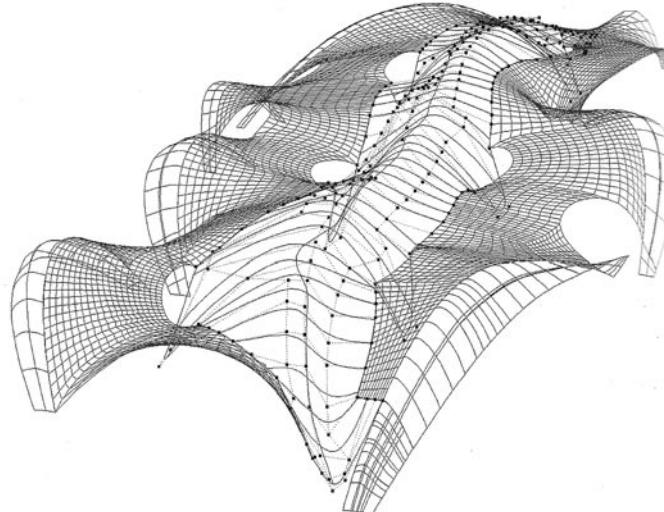


Figure 7. A Digital prototype, A controlled surface. (The digital and the material Balmond in conversation with Weinstock, Contemporary Techniques in Architecture, *AD*, v: 72, y: 2002; 46).

Digital Prototypes

The digital prototype is a data-embedded model that serves more as a computational construct or a generative infrastructure rather than a representative one. It is based on a field of interconnected elements, e.g. nodes, with a set of rules and limits. The coding allows manipulation and differentiation over the field. The catalogue of parametric configurations made possible by the current software is the tool of experimentation in this computational medium.

In today's information technologies as an open source, specific solutions can be designed to achieve the defined operational qualities. The design of scripts and programming and specific interface is the main infrastructure of this realm.

These bring other disciplines into the architectural discourse and architectural education can instigate an integration by introducing computational concepts and relational thinking from the initial stages of education, welcoming CAD / CAM technologies (**Figure 7**).

Figure 8. Spec, B+b, Fibrous workshop, and MT1. (Authors).

As the geometric model based on mathematical formula is both conceptual and computational, these defined prototypes are not always

4 INSTANCES OF DESIGN RESEARCH IN EDUCATION

	people	process	project
SPEC ongoing	with 2 partners 1 workshop with 10 students 1 competition entry with 2 students 1 installation with 6 students councillor engineer consultants: civil engineer computer engineer timber suppliers	research team 1 week workshop 8 weeks duration 2 weeks installation 3 weeks exhibition post research: 20 weeks	surface layout interpolated by contours zones informed with environmental and program data cad=cam dialogue
B+B working extra-curricular Yıldız Tech Uni	with 3 tutors 16 students IT company rapid prototyping company	3 day workshop 2 weeks production	conceptual thinking, contextual diagrams, mapping over time digital diagram model and its 3D print
FIBROUS ongoing	with 3 partners 1 consultant team 2 assistants included 1 workshop with 10 international students an arch center 1 major sponsor 2 universities, my cities	1 week workshop 1 symposium full time research	Islamic patterns, branching, bundling and weaving operations, component design and field investigations
MT1 study in curricular collaborative	with 3 tutors, 3 juries 27 students 5 clusters 2 countries new manufacturer 3 crits with invited jurors	14 weeks design studio 3 invited crits	folding, packaging, stripping operation in 1-1 scale with cardboard, plastic, rubber tubes with generative masterplan design

6. Spec_DR project, is an ongoing design research project of collaborative initiative by Akipek and Kozikoğlu investigating potentials of design by digital tools. From the series of experiments the project bred a competition prize (UIA landscape design award 2nd place) and two exhibitions. Currently the project is carried to a parametric design level creation of a field of multiplicity embedding potentials for manipulations and differentiation.

distinguishable. They can be orchestrated to embed time-space and movement; basic parameters of the contemporary. Each mode feeds differently into the design process and their complementary use enhances intensity of research.

EDUCATIONAL EXPERIENCES WITH PROTOTYPES

In the architectural education realm, the need to adapt the changing context of design research is on the common agenda. An educational model, which is based on iterative design processes and rectifications focused on fine-tuning the product, is out of date. Design as research with prototypes is the integrating force for the digital era (**Figure 8**). In this section, we introduce four instances from our experimentations in our architectural education and research environment.

Spec (6) is a design research project which has evolved in phases for the past two years. The aim of this DR project has been to experience an integrated *design and production process*, using the contemporary CAD/CAM techniques. The research is focused on an architectural system that is formally a continuous weaving of ribs changing shape in a gradient way and functionally laden with various programs ranging from architectural components to furniture. The design process involved generates a catalogue of setups and properties with an ability to adapt to different contexts.

Spec is produced from continuous model sections that are the assembly order and material dimensions listed in a computed synchronized data sheet. The dialogue of production and digital models is enabled by the customized script inserted in commercial software.

During this design research project we developed two material prototypes, the first utilised to develop structural principles, methods of weaving and joints and system behaviour. The second is a contextualised version that has been installed at various localities. Observing the interaction between users and context, we found out unexpected performances especially creating different forms of personal space. The feed back from six different installations now informs the setting up of a parametric configuration that will constitute a digital prototype.

Being Becoming (7): The scope of the workshop was generating through and working with 3D-conceptual diagrams which would involve “time and event”; externalize dynamic data such as car flow and pedestrian flow. Selection of the potential zone and activity, identifying its parameters; data collecting by sampling, and data mapping; data organisation; and creating a 3D-diagram which was close to constituting a problem by designing the interface of dealing with this data. Workshop ended with six group projects three of which were chosen for rapid prototyping. The aim is to design a generative abstract machine. This exercise involved what we call conceptual prototype. The rapid prototyped 3D-diagram enabled to understand the materiality of movement in space/time. Through processing and manipulation of site specific and collected data in digital media, students recaptured volumetric qualities invisible in the real context.

Fibrous Structures (8): The project explores complex fibrous cement structures in a multiple layered methodology. An investigation into structural assemblages (of fibrous structures), the workshop agenda is focused on the exploitation of parametric design techniques and structural

7. Being Becoming workshop, was a three-day workshop hosted within the IDCR course; a graduate course at YTU CADU, run by Nilüfer Kozikoğlu, Frederico Fialho and Müge Belek at HR computer lab of YTU. 12 graduate students from YTU CADU and a few graduate students from other design fields were the participants of the workshop.

8. Fibrous structures_DR project: The fibrous structures workshop is part of an ongoing research project initiated by Claudia Pasquero, Marco Poletto, Nilüfer Kozikoğlu and aims to explore the potential for design innovation, latent within novel technologies, such as design software and construction materials. In the specific, parametric modelling tools and fibre reinforced super-fluid concretes (by Lafarge) were the ingredients for an excursus in the realm of structural typologies and pavilion design. The workshop was held in İstanbul Technical University from the 23rd of February to the 2nd of March, 2007 and did terminate with a one day international symposium. The design focus was inspired by the designation of İstanbul as the Capital of Culture for 2010; creation of a pavilion as attraction point in the city.

9. MT1_course, is undergraduate architectural design studio project 2, run by Meral Erdogan, Fulya Akipek and Nilüfer Kozikoğlu over a term with 30 students. The course is an attempt to initialize a structural and operational understanding of material organizations in the department of architecture.

operations other than the conventional column-beam structures. These techniques were described via a matrix, containing a set of organizational principles (derived from Islamic patterns), of structural operators (3D assembling logics of weaving, bundling and branching), of concrete casting and prototyping techniques (concrete technologies), of site structural constraints and environmental fields. The methodology deployed accomplished the comprehensibility of many prototypes and processes. On the one hand there are the abstract parametric pattern studies as conceptual prototypes, schematic organizational component models and analogue prototypes; on the other, were the ones continuously in feedback.

MT1 (9) is a first year studio realised within the curriculum of the Faculty of Architecture at Yıldız Technical University. The tutors of all three sections in the class, namely Meral Erdogan, Nilufer Kozikoğlu, Fulya Özsel Akipek, together with teaching assistants Canan Akoğlu, Afşin Memari, Zeynep Oğuz, collaborated to form a studio program with specific focus on *learning by doing*, on a conceptual background of emergence and material organizations.

Two complementary projects were located across the Bosphorus, installations in urban park on one bank, and settlements on the other. In the initial project, five groups of students designed structures focusing on different materials as textile, metal, corrugated cardboard, PVC tubes and rubber. Starting with simple techniques for analogue models of paper folding, cutting, weaving or packing of tubular elements; the objective was using them as generative tools to get in dialogue with the context and to exemplify an architectural system that can be designed by coherence between structure, material, performance and the context. Five material prototypes were situated in the actual physical setting to further feed in the process. This phase was successful, however it lacked the versions of prototyping essential for design process due to time constraints. Learning by doing was effective pedagogically, however those students that did not follow a strict specific method failed in coming up with performative design. All groups benefited from the context interaction via enforcing 1-1 scale. This phase further fed into the next, equipping students with relational thinking and the idea of designing the process.

The second project involved design of a settlement pattern; a dynamic master plan for houses for students and academic personnel. The dialogue with the context and programme was the main factors of design. Thinking with diagrams and concepts such as flexibility or temporality, creating rules and patterns of living together and fostering diversity were the basic focuses. Design development over plan-section-facade trilogy was abandoned and a design method was suggested using sections and strip models instead. With the development of rules of grouping a master plan model did not end up in a frozen settlement but a generative 3D-diagram ready to be worked on, a conceptual tactile prototype.

CONCLUSION: REFLECTIONS ON ARCHITECTURAL EDUCATION AND PROJECTIONS

The taxonomy introduced above for prototypes is to expand the knowledge of their use and effect. The boundaries that distinguish one from the other are not always clear. However, rather than the distinction, the field of potentials that lies in their interrelation is the main topic of interest in this paper.

Those prototypes that are instrumental in the design process create continuous feedback and interaction and are versions of a process that is evolving. Prototypes are operational on the organization of their constituted parts; the relations of the parts and their coherence within a parametrically defined setup are adjusted and redefined in each instance. This quality transfers the prototype from being the testing of a product, to being the tool that informs a generative process.

In the assembly of this process, the method of producing the prototype is indicative. Almost indistinguishable with the method of design, the clear definition of the parameters and systematic application of the rules and constraints enables comprehensible and comparable as well as creative series of prototypes.

Material and scale are effective factors for interaction with design; the conceptual prototype is neutral and abstract, usually without a specific material or scale. In order to be operational, the material prototype entails loyalty to conditions and context specificity. This results in 1-1 prototypes as an operational scale. However for the digital, the clarity and coherence of the coded relations and the context are important to be generative rather representative.

The prevailing theories of complexity and emergence find reflections in the design pursuit. Evolving technologies provide new toolsets to work with relational material organization and its spatial and performative potentials. This fast evolution takes the focus away from perfection by repetition and gives it to innovation and intuitive conceptual and tactile experimenting via series of prototypes.

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Anahtar Sözcükler: tasarım araştırma; sayısal prototipler; kavramsal prototipler; fiziksel prototipler; mimarlık eğitimi.

MİMARLIK EĞİTİMİNDE PROTOTİPLER: SAYISAL ÇAĞ İLE BÜTÜNLEŞİK BİR YAKLAŞIMIN TEMEL ARAÇLARI

Sayısal çağın karmaşık sistemler ve kendiliğinden oluşum modellerine dayalı kavramsal altyapısı üzerinde gelişen mimari tasarım ve mimarlık eğitimi, günümüzde, süreçlere, materyal organizasyonlara ve veri organizasyonlarına güçlü bir vurgu yapmaktadır. Bu yazında, *tasarım araştırma* yaklaşımı günümüz kavramları doğrultusunda yeniden yorumlanmaktadır; sayısal ve kavramsal prototipler fiziksel prototipler ile diyolog içinde yeni tür prototipler olarak tariflenmektedir. Mimarlık eğitimindeki dört farklı deneyimimiz aracılığıyla, bu üç prototip arasındaki diyalog incelenmekte ve farklı türde prototipler arasındaki etkileşimin doğurduğu olasılıklar araştırılmaktadır. Çağdaş tasarım ortamı ilişkisel düşünmeyi; hesaplamalı ve sistematik tasarım yöntemlerini gerektirmektedir; sayısal ile materyal arasındaki sürekli etkileşim ve geri beslemeye dayalı olarak gelişmektedir.