OPEN DESIGN AS AN EDUCATIONAL TOOL IN ARCHITECTURAL STUDIES

Alexandros Theocharis VAZAKAS
Lecturer, School of Architectural Engineering, Technical University of Crete

ABSTRACT
The paper presents a course that introduces Architecture students to product design, materials, techniques and fabrication processes. The course uses a combination of digital fabrication tools and parametric design software – a combination often cited as "Open design". It also uses a rapid prototyping laboratory which among other things facilitates the transition from design to the actual product. Designing a chair is under a certain perspective no different than designing a building. There is a different context, different constraints but both are essentially design processes involving craft, geometry, materiality, function, structure and fabrication. The fusion between the disciplines of Architecture and Product Design attempted in this 4th year course focuses in a way of making architecture where the process of construction is as important as the form itself. A paradox is then created: by using the most advanced technological tools, the act of building is conceptually closer to its primitive form. The architect is also a craftsman, able to shape matter with his own tools. The paper presents the core theory behind the course and the results during its 4 year long history within the curriculum of an Architecture School.

Keywords: Digital Fabrication, Craft, Open Design, Associative Design

1 INTRODUCTION

Three reasons lead to the insertion of Product design into this architecture course:

- Scale: The design of easier to build artefacts creates a "shortcut" for the students. An opportunity to use a feedback loop, informing building design with material, process, and formal data.
- Friction with Fabrication: Construction processes, the notion of economy within construction contribute to the understanding of building construction as a process
- Functionality and structural stiffness: products (like buildings) have an even stronger need for a specific function and a structural integrity with respect to the construction process implemented.

The use of a rapid prototyping lab, especially one that fits within the norms of a fablab,[1] serves a triple purpose: Firstly, it greatly enhances the construction capacity in terms of speed and accuracy, secondly the fablab setup allows the implementation of almost any construction technique and thirdly the computer associated manufacturing allows for an "open design" approach.

Seen under a broader perspective, the course puts forward several critical issues: the relation between geometry, construction techniques and alternative ways of conceiving space, the issue of using invariants and variables in Architectural design, and finally the seamless integration of information technologies into the architectural profession.

There seems to be a bidirectional relation between geometry and construction techniques: on the one hand man is trying to impose abstract geometrical forms on matter, and on the other, material processing techniques seem to give birth to geometrical concepts. (e.g. ceramics and revolved

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[1] Fablab: A fablab is generally equipped with an array of flexible computer controlled tools that cover several different length scales and various materials, with the aim to make "almost anything". This includes technology-enabled products generally perceived as limited to mass production.
While fablabs have yet to compete with mass production and its associated economies of scale in fabricating widely distributed products, they have already shown the potential to empower individuals to create smart devices for themselves. These devices can be tailored to local or personal needs in ways that are not practical or economical using mass production. [2]

surfaces, textile weaving and matrix etc). Geometry itself presents a structure that consists of invariants. Mathematician Felix Klein in 1872 [1], proposed a taxonomy of geometrical theories in successive layers, defining geometry as the study of those properties of space that remain constant under the influence of a specific group of variations. Under this perspective, and while the only things that differ between Klein's layers are these invariants, one can notice a continuity between different geometries. Every "layer" expresses a different way of conceiving space. Within the discipline of Architecture, B. Cache links these layers with the techniques on which, according to G. Semper Architecture is founded.

Felix Klein's theory on the layers of Geometry can be expanded to Architecture: We can view each building as a Geometrical theorem which is structured on relations that remain invariant and allow for a certain width of variations. This leads us to the conception of the architectural artefact not as a single object but as a series. On top of that, with the aid of the proper digital tools, design of space can become collaborative and interactive.

The connection of Architecture to the technical professions which for Semper is critical, has been expressed after the industrial revolution with the Arts & Crafts movement and consequently with the Bauhaus school. There, it has also been linked with the contemporary technology of the time. Today information technologies having dynamically invaded all the layers of industrial production are continuously altering this relation of construction with technology. This relation constitutes by itself a field for research.

All of the above mentioned issues are put forward in the course "Associative Design" of the Department of Architecture at the Technical University of Crete. In order to present the structure of the course and the results thus far, it is necessary to refer to the relation of Geometry and Architecture under the theories of Felix Klein and Gottfried Semper, the concepts of variants and invariants as they appear in the works of Bernard Cache, and in those CAD/CAM technologies that contribute to a new vision of industrial and building production.

2 GEOMETRY, CONSTRUCTION, ARCHITECTURE

In 1872 as a professor of Mathematics in Erlangen University, Felix Klein formulates the first general overview of Geometry since 300 bc when Euclid composed his "Elements" [3]. The principal directions of the research thus far could be summarized to the study of variations related to non metric properties (projective geometry) and the questioning of Euclid's fifth postulate that lead to less defined and more "flexible" geometries. It is by basing his research on these directions, that Klein defined Geometry as the study of those properties of space that remain constant under the influence of a specific group of variations. As a result, Geometry is presented as a multi layered edifice, with every layer characterized by invariant properties. The four main layers of that edifice, those of the greater historic significance are Isometry, Similitude, Projection and Topology. Isometry, which deals mainly with distances and angles, is the geometry that studies properties left unchanged during translation and rotation. Similitude that alters length but keeps the angles and the proportions of lengths invariable consists for Klein a separate Geometry that together with isometry define Euclidean Geometry. Projective Geometry studies the properties of objects left unchanged during projection, meaning – between others- the bi-ratio of lengths, intersection and alignment. Topology studies the properties left invariant during topological transformations, namely stretching and distortion. [4]. Through Klein's reordering of Geometry one can distinguish the very nature of science which is the creation of more sophisticated invariants that allow for even more variations. These four geometries represent different ways of thinking about space and therefore different procedures in Architecture. Bernard Cache connects these geometries with the four fundamental techniques according to Semper: Ceramics, Tectonics, Stereotomy and Textile[2]. [3], [5]. According to this view each one of these techniques refers to primitive models that correspond to the basic transformations which characterize the Geometries recognized by Felix Klein. Ceramics refers mainly to revolved surfaces coming from the technique of the lathe. Tectonics cannot be separated from the problem of proportion. Stereotomy was the field of application of projective geometry and finally the founding pattern of textiles – the knot- is one of the most complex topological entities. Consequently, different geometries impose powerful

[2] In Semper's own words: " It will be shown that the fundamental principles of style in the technical arts are identical with those governing architecture, that the simplest and clearest expressions of these principles are to be found in the technical arts where they were first established and developed." [6]

restrictions in the ways we conceive, behave and act into space and have already defined Architecture from its very beginning although their theoretical foundation was yet to be structured.

3 VARIANT AND INVARIANT, ASSOCIATIVE DESIGN

Thanks to software such as Rhino or Maya, it is very easy to build and edit complex surfaces topologically by moving control points. This kind of processing though, is abstract and is not combined with structural and material parameters. Such a process refers more to the model of the Architect – Artist and to non standard but also very expensive structures. Based on the theme of "invariant by variation" that he discovers in Geometry, and on the close relation that the Architect should develop with the means he has in his disposition, Bernard Cache supports an Architecture that can be economical, constructible and consequently addressed to everyone. Nowadays writing code is one of the most important products of contemporary civilization but also the field of collision of the forces that define production. Within this framework the concept of associativity is already playing a decisive role in "standard" architectural production. The term associativity refers to software that allows composing an architectural project based on a long chain of interdependent relations, from its conception to the code that drives the machines that will fabricate the various connecting parts. Designing with associative software mainly means to transform a geometrical drawing to an interface of a programming language. Through associative design it is possible to control complex aggregations of different elements that we cannot draw one by one. This fact requires the process of insertion of components. In this case, the general model (assembly) is in a way an invariant able to support all the variations.

4 CONSTRUCTION TECHNIQUES AND DIGITAL TECHNOLOGIES

In the non standard Architecture envisioned by Bernard Cache, there should exist, prior to the constructed edifice, an abstract architecture, one that manages the flow of information with such efficiency that there are no intermediates between the designer and the machines. [7]. Nowadays, research has progressed and these technologies are becoming more and more accessible financially. The change related to the architectural product is taking place silently and follows the industries and market terms. CNC construction technologies can be divided into three broad, process based categories: machining or material removal processes; deformation, moulding and casting processes and fabrication or additive processes [8]. The Digital Fabrication laboratory in the Department of Architecture at the Technical University of Crete has been created in order to address most of the above mentioned categories. The Laboratory is fully functional since the academic year 2010-11. It is equipped with laser cutters a 3 axis cnc router and a 3d printer. It is addressed to students, teaching staff and anyone who wants to make something out of a digital file. In Architectural education, the close relation to the applied arts was founded at the Bauhaus School. Its program was among others, founded on Taut's belief that "There are no boundaries between handicrafts and sculpture or painting; they are all one: building."[9] The establishment of such a relationship within architectural education, besides the obvious fact of familiarizing students with materials and techniques, is building much stronger bonds with geometry, bonds that could be related to the roots of Architecture.

5 COURSE'S PRESENTATION. GOALS AND RESULTS

The course "Associative design" attempts to put forward all the above mentioned issues and to function in different educational levels. Firstly, on the level of familiarization with construction techniques, traditional and new, with the 1:1 scale, materiality and the experience of construction in general. Secondly, on the level of geometry and associativity, which is an exceptional tool for a student to structure his concept geometrically and follow design paths that he could not have been found otherwise. Finally, on the level of constructability that concerns series of objects but also the rules and terms of industrial production. The course, addressed to students of 4th and 5th year is developed around the following axes:

- Projects should follow a "Vertical" approach: from design to fabrication. The forms developed should be able to be fully elaborated within the Laboratory. In this way students experience designing and building a small project from start to finish. They gain valuable experience from the friction with real parameters such as the materials used and the need for structural coherence.
- Projects should use associativity as a means to handle complex geometries both conceptually and

structurally. In this way, besides dealing with the software (in this case Rhino Grasshopper) students get familiar with the logic of programming, with creating relations between forms and learn to hierarchically structure their projects.

- Projects should make extensive use of physical models created both manually but also with digital tools. These should reach even 1:1 scale in order to test both aesthetic and structural qualities.

During its four year long history, the course gradually focused on furniture design in the first semester and a building component design in the second. Every year a different material is chosen along with the specific techniques involved, and an attempt is made to "digitize" the material's traditional techniques in the lab.

The design task given for the academic year 2010-11 was to design a canopy out of plywood. This canopy should have a minimal use (e.g. define a space for 2 or more people), be associatively designed with no particular regard on the reasons of this associativity's initial parameters (could be sun path, topography or just a set of curves), be constructed at the school's Digital Fabrication Laboratory and use solely wooden detailing with no other material involved. For this last parameter, we used the research of Prof. .E. Burdek and J. Gros at the Hochschule fur Gestaltung Offenbach on the digital construction of wooden joints, as a basis for our detailing. Each team of students had to present a fully associative digital model, a physical model in 1:6, full scale physical models of the joints used the design process, plans, and the like.

At first, all teams experimented with sketches and small physical models. At the same time, they started elaborating the joints they would use and created wooden physical models of those.

In the student project of Figure 1, a set of curves defines a surface of double curvature. This is then constructed out of a "waffle" system of intersecting plywood beams and two ribs that form the transition to the ground. A set of triangles is placed between the openings providing shadow where needed and at the same time stiffen the structure in both directions.

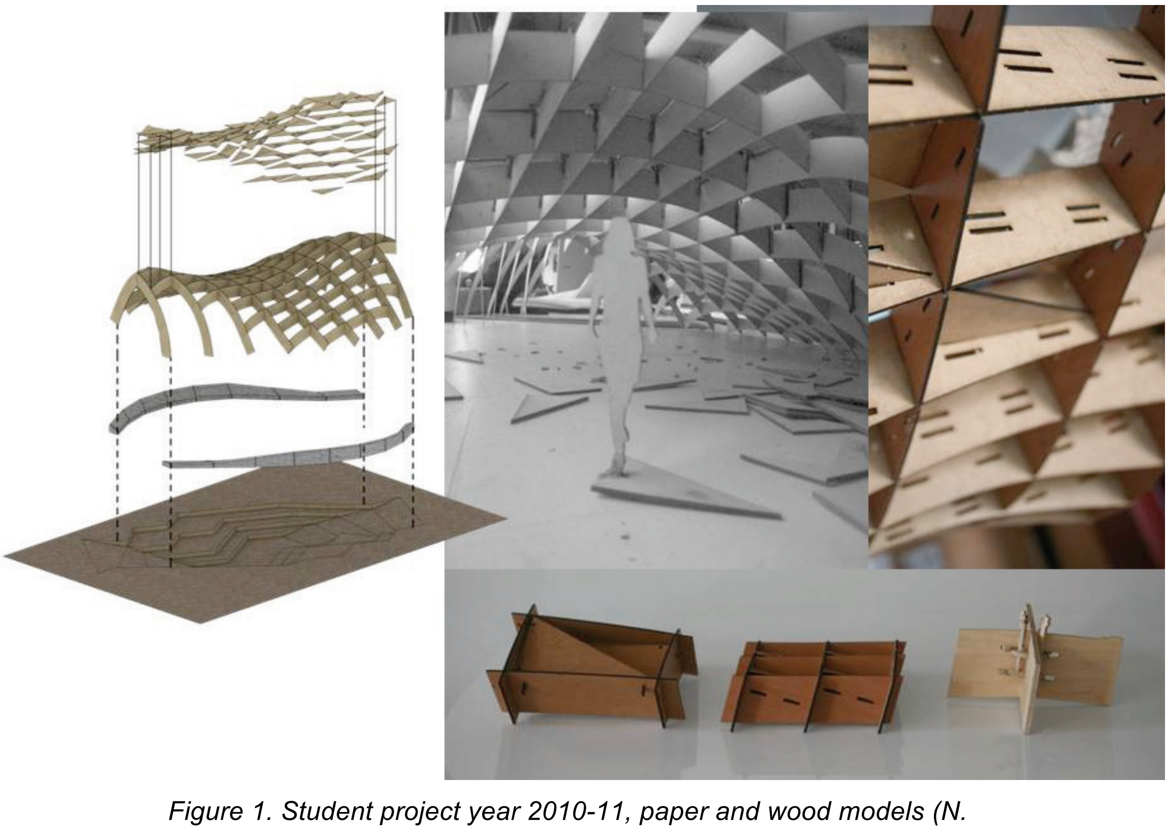

Figure 1. Student project year 2010-11, paper and wood models (N. Assimakis,M.Messaritis,S.Vlachiotis,G.Liakou, M.Giannadakis,E.Lionaki)

The academic year 2011-12 the design of a parametric plywood chair was chosen as a theme. Two examples are shown in Figure 2, one made out of press fit plywood panels and the other out of steam bent cnc cut plywood display the focus on the variability of the techniques.

Figure 2. Student projects year 2010-11, prototypes from press fit and steam bent plywood (E.Chronopoulou, G.Gratsou, E.Aslanidou / A.Andredakis, S.Konstandinidis, D.Tzagarakis)

For the year 2012-13, we used composite aluminium panels for the students' designs. Mainly the techniques of folding and rolling were implemented, as shown in the two following examples of chairs.

Figure 3. Student project year 2012-13, prototypes, folded and curved composite aluminium panels (X.Tzatha, E.Alexiou, N.Anthouli, A.Chatzimichali / S.Ntzoufras, E.Stathopoulou, M.Teliou)

The same year, a summer semester was introduced, where a shading device out of composite aluminium panels was developed. Various simulation software tools were combined with a parametric software in order to test and optimize the device's performance. Figure 4, shows the prototype in full scale that was constructed and put into place.

Figure 3. Student project year 2012-13, shading device from composite aluminium panels (S.Ntzoufras, G.Prosoparis,C. Freitas)

This year, for the winter semester the material used was fibre reinforced plastics. That decision led to fluid, double curvature forms for chairs, and a tedious process of making wooden and fibreglass moulds, in order to get to a prototype.

6 CONCLUSIONS

A fundamental relation between architecture, crafts and geometry is recognized, a relation which through the concepts of invariant and variation leads to a way of thinking based on continuity. Beyond the theoretical infinity of constructional and design capabilities provided by digital technologies, which very often lead to a designer's "easiness" there is a need for a deeper and more substantial connection of Architecture with man and society. A new paradigm of construction and design of space is required, a new relation between geometry and fabrication where digital technologies will be the leading factor, reuniting the human body with the almost forgotten language of construction.

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