Teaching Digital Design Principles to First Year Design Students

A methodology based on direct experimentation with physical construction assemblages

Stavros Vergopoulos1
1Associate Professor, University of Thessaloniki, Greece
1svergop@auth.gr

An educational methodology is presented that introduces basic digital design concepts to first year design students. The methodology differentiates between four fields in design thinking namely Form, Function, Context, and Structure/Materiality and focuses on Structure/Materiality that is approached as an assemblage of components. Components are categorised in respect to their geometric and structural qualities with reference to the elements of 'point', 'line', 'surface' and 'volume'. Components are interconnected to corresponding design techniques that are used in order to compose complex forms and are outlined by a rule of composition. The primary technique of 'point' structures is based on the notion of multiplicity and repetition. 'Line' assemblages introduce to the concept of load bearing structures and they can effectively describe hierarchical associations. 'Surface' elements are used to explain the results of transformational processes upon structural behaviour. 'Volume' techniques refer to the notion of integration and directly affect the overall performance of the structure. For each one of these elements, the students are asked to work directly on physical assemblages with ready-made components which are chosen in respect to their structural characteristics and to describe explicitly the whole process in drawings and diagrams.

Keywords: Digital design principles, Experimentation, Assemblies, Components

Introduction - Background

The use of digital technologies gradually becomes a common tool for architectural discourse and it is widely used by architecture students during their studies. Access to parametric and algorithmic design tools, and fabrication technology, changes and evolves the architectural design process. However, while the organised teaching of digital design is found in specialised postgraduate courses, in undergraduate architectural education the usual teach-
ing methodology is still the traditional design studio where the educational model is the simulation of the design practice (Papadopoulou et. al, 2007). Digital tools are taught as auxiliary drafting or modelling tools. According to this educational model, design process is divided in stages that usually starts with the theoretical analysis of a given program and continues with the interpretation of site and context conditions, and then a schematic design is initiated that is based on existing typologies or, as it is quite often recently, on precedents as images found through the internet. Explorations are supported by paper-based sketches. When an architectural form is stabilised, design development begins which is supported by computer drafting, modelling and imaging tools.

Scholars in design pedagogy notably argue that digital design is a unique field of design endeavour relying on its own theoretical sources and methodologies and promoting its distinctive ideology and formal content. Digital design includes new concepts about the meaning of form, an alternate understanding about the nature of function, materiality and performance, and new generative and transformative processes that are used to progress in design (Oxman, 2008). All these indicate a need for new educational models and a different pedagogy. Of course, a lot of schools have specialized courses particularly during the later stages of architectural education that introduce and explore the potentials of digital design. Students realize at this late stage that digital design is a whole new enterprise of design thinking and not just a technical tool that support and enhances a standard conventional practice. As a result, there may be a number of students that are thrilled with the new prospective and continue to study it in dedicated postgraduate courses. Yet, the greater number of them simply returns to their known practice and digital design for the non-specialists still remains a technical subsidiary field.

This paper presents the course “Introduction to Architectural Design” at the School of Architecture of Thessaloniki. The course takes a transversal approach to the problem mentioned above. It introduces to first year design students an educational methodology that describes the totality of design activity but relies on design knowledge and concepts that derive mainly from the field of digital design. It utilizes design experimentation with simple techniques that refer to the analytical, constructive and ontological way of thinking that characterizes digital design without the necessity of using computerized systems or understanding their technicalities.

Description of the course (case study) - Basic principles

The course adopts a descriptive and generalized view about design. It explains the four major fields of interest that affect design and outlines them as the field of Function, Context, Form and Structure/Materiality (Bielefeld & El Khouli, 2013). Design is defined as the effort to achieve a fit between the tendencies and requirements, the constraints and possibilities that arise within these fields. Thus, design is not seen as a standard problem-solving routine in which the final outcome is entailed by some given objectives. Instead it is a personal and distinctive highly dynamic cognitive activity in which instances of information within the above-mentioned fields and the interpretation by the designer plays an important role. Function and Context are abstract fields that are difficult to attain. They are conditioned by theoretical, varied and imperceptible knowledge sometimes outside the area of design. Form and Structure/Materiality are more tangible and concrete fields as the knowledge that condition them can be more explicitly expressed and has to do with the physical counterpart of design.

As stated earlier, the standard conventional design process starts with resolutions within the field of Function, taking into account Contextual restrictions, and continues with explorations about the outline of a Form and the adoption of a Structural scheme in order to accomplish the constructability of the designed object. However, this is not the case for digital design. For digital design these fields are not as distinct as they appear in the sequence above.
Form and Structure, for example, are bond together with geometric associations that allow modifications in one field to trigger changes in the other and vice versa. This supported a whole new endeavour to flourish, known as form-finding. This initiated by the experiments of Frei Otto (Nerdinger, 2005) and continues today with the approaches of Digital Tectonics (Leach et. al, 2004). Furthermore, the process-oriented character of digital design and the parametric descriptions of the designed object allow us to assume that digital design works in a continuum and permits cross layer assertions and cross scale judgements to be made.

As such, at the first part of the course "Introduction to Architectural Design" students are asked to approach the Structure/Materiality field of design. In addition to what stated above, the reason for doing so is to unlock the creative potential of students who when entering the school come with a series of presuppositions, reservations and clichés about architectural design and form that lead them to highly conventional and superficial results. The focus on the activity of form-finding directs them to experimentation rather than to the adoption of ready-made solutions. Later, during the second part of the course, the students will deal with the rest of interest in design: Form, Function, Context.

Method of attaining a structural model
Structure is approached in terms of components (Zarzycki, 2012). Component-based design is a well-known approach in digital tectonics. It was chosen as it brings a direct attention to materiality and process in design. Furthermore, component-based design can be realized by students with limited knowledge on design theories and focuses on the actual and the performative aspects of design. It allows students to start experimentation from the beginning of the educational process without the hesitations associated with big scale decisions. Above all, it enhances their creativity and spatial thinking and grows their interest on the making of architecture.

Four different categories of components are introduced to the students. These are chosen in relation to the geometric and structural qualities, the techniques that are used to interconnect them during construction, and the potentialities of the outcome. These categories refer to the basic geometric elements of point, line, surface, and volume. For each of these categories, students are asked to use ready-made components and to construct a physical assemblage. The assemblage is constructed straight in real scale without the use of prior drawings. Different components are used for the different categories. Small pieces of wood or plastic, seeds, balls, etc. for structures that refer to point, sticks of wood, wires, strings, etc. for linear systems, large sheets of paper, textiles, plastic sheets, etc. for structures that refer to surface, and only in the case of volume students can construct solids as components. Then there is a great deal of experimentation in order to find out the structural properties of the components and to define the technique that is used to combine them and to create stable assemblages. Students are asked to use a single interconnecting technique for each assemblage but variations are welcome. The whole construction process is documented and presented in posters and diagrams. Emphasis is given to provide an explicit description of the logic, the rule or the process that underlies the interconnecting technique.

Point-like components refer to architectural forms that are made with small scale elements like bricks, stones, small pieces of wood, etc., without the use of a load bearing frame. The main characteristic of these structures is the notion of multiplicity and repetition. They are conditioned by a rule according which pieces are put together. Rule-based design allows the generation of spatial complexity based on simple principles (Valena et. al., 2011). The result is a usually a surface that tends to display patterns. The surface is theoretically borderless unless edges or shapes are imposed by another rule at a higher level. Therefore, rule-based structures are good demonstrations of the notion of ‘field’. As the rules act at a low level, clear conceptions of the process reveal unforeseen formal layouts, in a bottom-up fashion,
which are structurally interesting and systematically coherent.

For linear components the reference is architectural forms that are made either from rigid elements, such as wooden sticks, iron bars, etc., or soft and elastic ones, such as wires, ropes, strings, etc.. The main characteristic of these structures is that different elements play a different role within the whole structure and, therefore, are good demonstrations of the notion of hierarchy. The whole structure can be described as a series of hierarchical associations. In addition, the issue of structural articulation is discussed that refers to the constructive qualities of the connection between the different elements. Linear structures are actually that most common types of load bearing frames in architecture and their discussion includes issues on structural behavior such as with the notion of tension and compression. Tensegrity constructions, in particular, refer to a specific structural system of isolated components under compression inside a network of continuous tension, arranged in such a way that the compressed members (usually bars or struts) do not touch each other while the prestressed tensioned members (usually cables or tendons) delineate the system spatially. They were explored by Buckminster Fuller and they are very popular in digital design studies (Buckminster & Marks, 1960). A specific kind of linear systems is the weaving systems. Weaving systems have been studied extensively in digital tectonics. They are effectively rule-based systems in which two distinct sets of threads are interlaced at certain angles to form a fabric or cloth. Other methods are knitting, crocheting, felting, and braiding or plaiting. An interesting technique is when the combination of different rules, or variations of the same rule, are used on the same surface. This produces varied and unexpected effects (Spuybroek, 2009).

In constructions that use surfaces as structural components the main attribute is the differentiation in spatial behavior that each single element attains in respect to conditional aspects. In other words, a single surface can be an ‘inner’ wall or an ‘outer’ wall, can be a ‘roof’ or a ‘floor’, depending on its relation to other elements. Hence, surfaces are appropriate to study the notion of continuity. The exploration of the new tectonic and economic potentials of con-
continuities of all types (spatial, programmatic, visual, technical, environmental, formal and symbolic) was brought about by the merging of computational design and digital fabrication (Lynn, 1993). In relation to structural qualities, it is quite important to note the different structural behavior that single elements attain when simple transformational techniques are applied to them such as bending, stretching or folding. Thin surfaces can become rigid and self-retained. A whole new area of potentials arises when soft elastic surfaces are used in combination with control points that regulate their tension and geometry. Frei Otto has studied a great variety of these constructions and used them for the design of the München Olympic Games shelters (Otto, 2009).

Finally, constructions that refer to volume use bigger scale solids as components. Solids are made from cardboard boxes, balls or polystyrene blocks and the students were asked to compose an assemblage using multiple times a single transformation. As volumetric constructions have been used extensively in architecture, there are a lot of compositional practices and solid transformations which are worthwhile studying. Volumetric transformations are difficult to be defined by descriptive geometry and have been accommodated in early modelling software. Boolean operations (volume union, subtraction, intersection) were among the first techniques used in 3d modelling in order to create complex forms. More complicated transformations, such as packing, draping, stacking, bending, stretching, twisting, splitting, etc., are explored by the students in physical assemblages. Yet, such constructions cannot actually be seen as structural systems. Volumetric compositions tend to be closed and integrated and they are usually approached as finalized forms.
Structural model and design process

The second part of the course approaches the rest fields of interest in design: Form, Function, Context. A new brief is given to the students requiring the design of a light construction to accommodate outdoor activities in the University campus. Students are asked to use as reference one of the assemblages already made and to develop the design based on the same structural and formal principles. The students continue to work on physical models but now issues of scale, access, orientation, size, distribution, etc. are discussed. They have also to confront a realistic brief on a real site with all the restrictions and consequences that this entails. Yet, they retain a structural model that is used as a basis for the development of the design. As with the previous part of the course, most of the teaching within the studio follows a direct dialectical tactic with one-to-one tutoring and direct work with the assemblages. As such, digital design concepts are not defined and explained beforehand but they are approached as they are revealed during design and discussed with the tutors. This might look a little vague and dissimilar. However, in most of the projects the notion of design as a system whose properties arise from the relationships between its parts is discussed. And of course, the notion of a parametric structure as a core frame upon which the rest of design builds up. Nevertheless, the bigger differences from the conventional approaches discussed in the introduction of the paper refer to four major shifts which are not explicitly discussed with the students, but play an important role. Firstly, the abandonment of the modernistic design ontology that is predicted by formal, definite and typological knowledge. Secondly, the merging between conception, generation and production within a single medium. In our case this was the physical assemblage (to the extent that it encompasses design changes). In digital design, the medium is a central dynamic digital model that holds all design information. Thirdly, the relief of design from strong concepts of representation. Image is not any longer the central part of design and precedents play a limited role as directing forms. Finally, the development of design is based on emergency and transformational processes that occur through experimentation and the direct contact with the assemblage. Development is not only the refining and amplification of already conceived forms. These shifts point out to a new orientation in design education roughly defined as “digital design thinking” that may become the core of a new pedagogy in design (Oxman, 2006).
Conclusions

To sum up, the architectural course presented introduces basic digital design concepts to first year design students. The educational methodology differentiates between four fields of interest in design, namely Form, Function, Context, Structure/Materiality, and proposes a teaching tactic in which the students approach firstly Structure/Materiality. A structural model in the form of a physical construction assemblage is used that is based on geometric components. Design concepts and techniques appear and discussed through experimentation and the direct contact with the assemblage. At a second stage, the rest of design fields are approached. It is quite difficult to evaluate the success of the educational experiment in respect to digital design knowledge that the students gain. At a first glance, the students begin to support their projects by arguing on the logic of their designs, the clarity of the principles and the coherence of the rules. This seems to be a goal as usually students at this stage tend to refer only to personal preference when supporting their projects. It would be good though to observe the same students at a later time and courses that explicitly present digital design principles and methods. However, this is difficult with the current structure of the educational program of the school and could be addressed with additional dedicated research. Nevertheless, the focus on the making of architecture and on form-finding activity and the experimentation with physical models and explicit rules of composition seem to unlock the creativity and innovation and give quite impressive results from students with limited experience in design.
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