Computational Thinking and the Architectural Curriculum

Simple to Complex or Complex to Simple?

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Recent trends in architectural education and practice have encouraged the use of computational tools and methods for solving complex design problems. Newer technology can augment the design process by applying progressively more-advanced computational tools. However, the complex nature of these tools can lead to students getting lost at the skill-building stage, they can become trapped in computational design terminology, leading to designs of limited spatial quality. This paper introduces a pilot study from Izmir University of Economics (IUE) for the integration of computational design technology in the undergraduate architectural curricula, based on a workshop series using a top-down teaching strategy.

Keywords: Basic design, learning outcomes, keyword analysis, visual scripting environment (VSE)

INTRODUCTION

With the widespread use of digital media, the integration of digital tools with architectural education and discourse is a common topic for design educators. Open-source parametric and algorithmic design tools are pushing the architectural design process by challenging traditional pedagogical methods. Several studies have been conducted in search of the extents and methods by which digital tools are integrated to the architectural curriculum. Oxman (2008) presented an experimental design research studio on "the exploration of digital architectural concepts" as a pedagogical framework for educating the digital architect. Ozkar (2007) offers a design teaching approach of "learning by doing" by integrating the notions of design thinking and computing to the first year of architectural design education. Colakoglu and Yazar (2007) present a graduate course entitled "Designing the Design" focusing on computational thinking and the new emerging language and methods of design. However, few studies display the outcome of student learning via digital design and fabrication courses which focus on the junior years of architectural design education. Early interaction with digital tools in the early stages of architectural curricula can serve to shape the remainder of the education. To evaluate the computational approach for foundational and architectural design education, this paper aims to make a discourse analysis based on the interrelations between the process and the outcome of innovative student work from a workshop series for first year basic design and architectural design students at Izmir University of Economics (IUE).
OBJECTIVES AND METHODS

For several decades, design schools have incorporated CAD with design studio and non-studio subjects (Mark et al. 2001). Some schools introduce digital technology within isolated courses in order to computerize drafting skills, while others integrate computation to design studios. Kvan et al. (2004) identify four levels of digital media interaction in design curricula: general computer use, application of digital media, engagement of design computation, and advanced exploration of design theory and methods. Concerning these levels of interaction with digital media, case studies at several universities for graduate (Schieck 2008) and undergraduate programs (Duarte et al. 2012) expound the teaching strategies and their merits. In Duarte, Celani and Pupo's article, a comparison of two universities with alternative methods for the integration of digital tools in design education display which strategy to follow while changing the architectural curriculum. Referring to Duarte's two examples, he defines a discrete studio model with an updated computer curriculum versus the traditional curricula with a bottom-up approach. However, it is not clear how the basic structures of design curricula need to change in order to effectively incorporate state-of-the-art technologies.

How do we allow for transformations that would satisfy current advances in digital technologies within an established curriculum? One school of thought is that such additions be piled-on towards the end, when the basics of the traditional curriculum have been covered thoroughly; the logic being that students are sufficiently equipped in traditional design methods to begin applying advanced digital tools. More and more however, as these technological advances are constantly being further developed, we find students struggling to comprehend, never mind execute, the surrounding language. It would appear, regardless of the connectivity between architectural design and its digital methods, that the skills of one are in fact rather remote from those of the other.

With this in mind, we explored two directions of skill learning: top-down and bottom-up. As defined in Sun et al. (2001), top-down learning goes from explicit to implicit knowledge, while bottom-up learning is the opposite; going from implicit to explicit knowledge. In our case we wanted to explore the interactions between the two types of learning, particularly in terms of one type giving rise to the other. As part of an internal review of teaching practices within the architectural department of IUE, we implemented a set of intensive one-day workshops for digital design, requiring no prior knowledge of software language. For the first workshop, we posed a simple first-year design problem to be solved by relatively complex digital means including the digital fabrication of each model. Not only did the end results prove more than satisfactory, the students themselves quickly lost their initial nervousness and reported enjoying the tasks.

BACKGROUND

The Faculty of Fine Arts and Design at IUE has a first year curriculum based on an interdisciplinary studio set-up for all departments; fashion, architecture, interior architecture, industrial design, and visual communication design. Students in the first year of their design education will experiment with materials and tools for the first time as, in Turkish education, there are no basic design classes prior to university. The design studio is at the core of architectural education, where students are given design problems which have to be solved holistically through background research and explorations in two and three dimensional media. In the basic design curriculum, shapes, forms, materials and tools are abstract rather than referring to professional conventions. Basic design courses explore abstract formal composition, while technical courses emphasize new materials and processes as inspiration for innovative architectural forms and structures. Independent from professional disciplines, the curriculum is based on teaching the designerly way of thinking. This pedagogy "learning by doing" is based on hands-on expe-
rience for deeper understanding of creative skills and designerly knowing (Cross 2001).

Learning by doing, or experiential learning, is a pedagogy based on hands-on experience rather than uniform second-hand lectures to form a creative individual (Ozkar 2007). Ozkar's pedagogical framework, based on the Middle East Technical University (METU) basic design program, describes the pedagogy that we follow in IUE. Following Bauhaus pedagogical approaches developed by Walter Gropius in 1922, the first year of basic training in the Art and Design Studio FFD 101/102, students experiment with color, shape and materials, with no specific functional or spatial requirements (Kvan et al. 2004). Running parallel with this studio class, another studio approach is Introduction to Architecture (ARCH101/102) which follows the Ecole des Beaux Arts approach. Often, students are given a group of precedent buildings to analyze through plans, sections, and elevations from which they are expected to build scale models. The students learn from precedents, not only evaluated by skills and mastery of representation tools, but also by articulating the formal, spatial, and material content of architectural ideas. In FFD 101/102, students are encouraged to produce their own creative designs based on their subjective perceptions, as opposed to ARCH 101/102, where students draw inspiration from existing designers and architects.

In terms of course schedule and credits, the emphasis is placed on FFD 101/102. A deeper insight to "learning by doing" will help us to explore the teaching strategy in our university. A design studio is an atelier "environment where students test out theories, ideas, materials, constructions, and similar productions, as part of their design process" (Ozkar 2007). Directly introducing tools and materials, this pedagogical model aspires to develop the craft that a designer needs by testing visual and spatial qualities. Following the discrete model curriculum, traditional design tools such as technical drawing, cardboard modeling and free-hand sketching, are introduced to students in separate first-year classes which enable them to work on basic design tasks. Due to the emphasis on interdisciplinarity and transdisciplinarity for first year, the second year design studio focuses on spatial relations, functional requirements and structural integrity, on a more architectural design language. Following the same Bauhaus pedagogical methodology, second year gradually introduces the architectural thinking. However, digital tools are rarely introduced in the studio classes, but rather as separate supportive courses.

To date, computational thinking is not fully integrated to the curricula. The interdisciplinary approach has brought interactive pedagogical teaching methods and a need for independent professional classes for each discipline leading inevitably to a discrete studio model. This pedagogical model brought the disadvantage of CAD/CAM courses being conducted independently of the main design studio, leaving computing as an add-on. A good example would be the FFD Computer Aided Technical Drawing course which teaches technical drawing skills to students via computer. Based on student evaluation of the separate first year CAD classes and observations made in their second-year architectural design studio, we decided to search for ways of integrating CAD/CAM tools into the design studio. To avoid the disadvantages of the discrete studio model, computational design tools and methods were applied in one-day workshops.

WORKSHOPS
The first-year workshop "magnetospheric(de) formations" was conducted as a single unit basic design studio curriculum for all design students (Varinlioglu et al. 2015). The challenge was to offer the same complex computational design problem to all students, having no prior experience in VSE or with digital fabrication. For this workshop, we explored cyclic relations among the computational definitions of magnetic force, their applications to the form finding process, and the fabrication of digital models by laser cutter. Given the simple design scenario of an outdoor park, students were asked to design a children's playground by deconstructing and exploring
the holistic algorithm of a magnetic field. With a scenario borrowed from the more complex graduate level, we introduced the definition of magnetic behavior with few contextual requirements or ergonomic concerns, within the Grasshopper VSE. Pre-cooked Grasshopper definitions and the given design task allowed students to explore computational analytical thinking and designing methods, while pushing them to experiment with forms by changing parameters. The workshop would only accept digital fabrications created with the CAD/CAM tools available in the modeling lab. These constraints allowed students to focus on exploring iterations of the free-form design, while introducing a level of freedom as the craft of model making would be augmented by the CAD/CAM tools (Figure 1).

The second-year workshop “VERTIC algorithm” continued with parametric modeling as an augmentation of the first workshop. This intensive one day workshop focused on altering part of the Izmir cityscape, the silhouette of the historical “Asansor” region. This site is well-known for its urban elevator, a functional historical structure that connects two levels of the city. Today, besides functional usage, the Asansor also serves as a touristic destination, but the bare cliff still remains as a background to the site. The objective of this study was to design vertical circulation elements in urban scale and to decide on the level of intrusion with respect to topography, landscape, urbanscape and historical cityscape (Figure 2).

For this workshop, requiring a little experience in VSE’s and digital fabrication tools, students were given a slightly more complex design problem. Using the same VSE as for the first workshop, the fo-
cus was on making renovations to the vertical backdrop of the historical region. In contrast to the first workshop, students had to deal with a given topography within an urban context related to their architectural design studio project. Borrowed from a graduate level computational design studio, five keywords were given for this second workshop: force (magnetism), seed, fold, parasite, and melt. The pre-cooked Grasshopper definitions were given for three keywords (force, melt and parasite), while the rest of the groups searched and created their own VSE definitions. Besides five compulsory keywords from computational design, we mentioned additional architectural/design keywords to help students develop initial design ideas. These keywords were paired with similar keywords from computational design terminology, as in: cityscape/urban context, architectonic/s/form, swarm behavior/pedestrian movement (Figure 3).

**INSTRUMENTS**

To observe the level of students' learning, data was collected on their final products by four methods:

- Observing students' work process
- Completing questionnaires after students' final presentations
- Conducting informal interviews with participants at the end of the desk critique
- Having jury members evaluate students work

The goal of the questionnaire was to emphasize discourse analysis based on keywords. We asked participants to evaluate all eleven team projects based on the presentation boards shared on the workshop blog. The presentation boards included hand-drawn sketches and models, the initial grasshopper definitions, and the final CAD/CAM models which were superimposed on a physical model of the historical landscape. In addition, open-ended questions were included in order to reveal patterns of the students' learning experience, as based on the keywords. The students were then asked to analyze their own work, as well as each others work with these given keywords. Further questions focused on analyzing the work through basic-design versus architectural-design terminology. The jury evaluation of students' work included four dimensions of the aesthetic, functional, environmental and computational aspects.

**RESULTS**

The expected result of the first workshop was to equip students with analytic thinking through CAD/CAM tools, without colliding with their design skills. This was achieved by a top-down teaching approach for computer tools and a bottom-up approach in designerly thinking. Simple design problems with few constraints allowed students to concentrate on the skill building process. The second workshop concentrated on design thinking with relatively complex design problems. Thus, from complex to simple, the VSE allows the flexibility of dealing with more complex

![Figure 3](Keyword analysis matrix based on the questionnaire of the second workshop.)
design problems in second year.

Figure 4 shows the pre-cooked Grasshopper definition given to two different groups. The first group (group 1 "blocks" in Figure 3) researched various alternatives within the same pre-cooked definition, while the second group (group 5 "experience" in Figure 3) used minimum modification to this definition by simply changing parameters and focusing on the digital fabrication outcome. As a result, the first group augmented the definition to a more spatial level within the urban context, but had difficulty in the digital fabrication stage. The second group targeted the outcome much faster but ended up with poor spatial quality. Based on the learning outcomes of the second workshop, the variety of the keywords given lead to free-form exploration of design ideas, however creates no spatial diversity.

Later, the questionnaire proved that the first group with little modification was a stronger example of targeting the keyword as the reviewer students could accurately infer that they used the keyword "force". The second group, resulted in an evolution to the pre-cooked definition, and the reviewer students were unable to say that they used the keyword force. A further analysis was based on two keywords referring to the same concept, from basic design terminology and complex computational thinking respectively. As expected, students were seen to use familiar terminology rather than those newly learned or implemented from the workshops. In all, the technology helped produce fairly good computational results even if, at this initial stage, some students were using the tools without appearing to build a great deal upon the architectural discourse.

CONCLUSION

By means of a series of one-day intensive workshops, without prior training, groups were introduced to the basic concepts of parametric design thinking and CAD/CAM tools. These groups then had the opportu-
nity to apply this knowledge to developing solutions for the design problems posed. Having neither the architectural nor computational experience to solve design problems independently, the combination of newly acquired skills was applied to great effect and satisfactory solutions were created from this bottom-up approach. However, when asked to choose from more than one computational design keyword, they struggled to develop their architectural design solutions or to fabricate good physical models. Thus, starting designs from single keywords and VSE definitions resulted in more competitive and creative outcomes during the design process. In that sense, we propose to integrate the bottom-up approach which proved so successful in the first workshop into our future curriculum.

Looking towards the future, we aim to continue with these workshops alongside the normal architectural curriculum in an effort to ease computational design methods into the everyday thinking of students. To this end we are updating our curriculum to include digital design classes at a basic design level. Our initial effort of including computational thinking into the architectural curriculum was through an update in the computer aided classes, run separately from the design studio. Within our curriculum, an initial stage which includes computational tools to first year students is achieved by the FFD Computer Aided Technical Drawing course. As the name implies, the course is intended to begin technical drawing via computer. Besides design classes, this format initiates the process of building computational skills. By using a basic emerging form and by following the parametric modeling and technical drawing techniques, we experimented with inter-representational tools of modeling, VSE, coding and representation tools in the digital environment. Based on the learning outcomes of the students, a simple design problem was shown to help students explore computational thinking. In the coming years, a more thorough analysis on students' learning outcomes will be repeated with this sample group of students until their graduation.

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