LEARNING BY DOING IN THE AGE OF DESIGN COMPUTATION

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Abstract. A design teaching approach of integrating the notions of design thinking and computing in the first year of architectural design education is introduced and discussed. The approach aims to enhance and bring up-to-date the educational practice of “learning by doing” in the first year foundations curriculum. In the studied example, the analytical phases of thinking in a simple design task are systematically and visually recorded. This documentation is incorporated to the design process as a means for the students to consciously reflect on their design thinking.

1. Introduction: Learning by Doing before Computing

Learning by doing, or experiential learning, is a phrase that is representative of the pedagogy articulated and advocated a century ago by the American philosopher and educator John Dewey (1916) as part of an agenda of implanting democracy in education. This pedagogy is based on the general idea that hands-on experiences leave deeper marks towards the development of the creative individual than those induced by uniform second-hand knowledge. Recognizing artistic activity as a mode of intelligence, John Dewey devotedly promoted the hands-on nature of artistic production as the primary means for elementary education (Eisner 1972).

The above point of view finds its parallel in the way William James (1908) couples learning with the ability, endorsed by the senses, to discover new part-relations as two indispensable parts of reasoning. Along this line, learning by doing within the extent of this paper specifically implies the using of the hands in coordination with the eye, and the other senses where necessary, to govern tools within a context of artistic production.

Learning by doing in the Modern framework is manifested most articulately in Dewey’s writings and his efforts at the Teachers College at Columbia University between the years 1905-1930 to establish active learning in education. Historically it is traced back to the pedagogies of early 19th century child educators Johann H. Pestalozzi and Friedrich Froebel who
separately started the kindergarten tradition in which children draw, make, build, play, and at the same time learn through sensory experiences of all kinds (Naylor 1985). Hands are at work in supplement to the eyes in acquiring not just abstract knowledge but also experienced (tested and personalized) knowledge. To make it all possible, “doing devices,” the tools, procedures, media or game objects incorporated by the educator as the means to do, are essential to this method (Schank 1995).

2. Learning Design by Making

Dewey’s legacy and learning by doing is today at the core of a widely practiced model of design education with the design studio at its center. It is yet open to improvement and thus has been a critical reference to multiple studies in artificial intelligence and education sciences, as well as those in the fields of design computing and design inquiry, notably by Gero (1999).

A design studio is ideally an atelier, open 24 hours, inhabited and kept by the students. It is an environment where students test out theories, ideas, materials, constructions, and similar productions as part of their design processes. Because it is a shared space, students are able to work together, and follow each other’s processes.

In pedagogical approaches from the lineage of the Bauhaus, experiential learning in the studio is rigorous especially in the first year of instruction when the subject matter is the first encounters with the means of doing. The foundations curriculum, which starts off the design education, encourages learning by making, where making implies literally the hands-on production. Directly involving the tools and materials, this approach aims to develop "that craft" which a designer must possess: creating while constantly testing out visual or spatial outcomes of ideas. The subject matter learnt is making itself in the very broad sense: how one makes, as part of designing rather than making a particular object in a particular way. This generalized experience implanted in the very first year of architecture education is adaptable to other contexts to come in the advanced years of education.

Today, tending towards the integration of digital tools, architectural design education is going through a transformation. Design students are now immersed in working with digital tools as much as and even more than in working with traditional design tools. The common ways in which they make their design models, the materials and the ways of production that the aspired architecture profession deals with are changing. Digital fabrication is becoming more and more the key to integrated design solutions.

From the point of the educator, the means to teaching design are altering in parallel with the tools. How the notion of making in the studio prevails in the age of technology remains to be investigated, along with how learning by digital fabrication is a continuation of the making learnt in the first year.
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Rather than yielding to CAAD as advanced ways of designing and as an add-on to architectural design curricula, educators can transform the common tools of the profession. Garvey (1997) suggests interdisciplinary links, in order to sustain the richness of hand-mind relations across media in art and design education. Along similar lines, Ivanka and Temy (2005) propose to reconsider the traditional design teaching ways within a modern view, in order to make the most of what has been long tested.

Traditional design tools such as technical drawing, cardboard modeling, and freehand sketching are usually introduced to students in the first year as means to work on design tasks. Then again, if making is to find a way into digital culture as implied above, digital tools should make their way into design education at this very fundamental level. Not to overload the already intense curriculum of the first year by introducing computers as a primary medium for design, this introduction may consist of the theoretical framework that enables one to make the most of tools in general. The traditional tools can be enhanced via design computability as a technique for governing the design process.

Building on discussions of ‘learning design by …’, this paper inquires which aspects of design computability can be introduced at the level of the first year. It is a proposal for first year curricula in schools that tend towards digital fabrication in senior level design studios. The motivations and results of strategies tried in a first year design curriculum are discussed through a sequence of basic design assignments and the contents of a supplementary course that puts emphasis on analytical thinking in design.

3. Learning Design by Digital Fabrication

Students in the first year of their architecture education, learn to experiment with materials and tools effectively for the first time. In the basic design curriculum, forms, materials and tools are all abstract, due to the reason that, independently from all these ingredients, the subject matter of teaching and learning is mainly what Cross (1988) has named the “designerly way of thinking.”

Nevertheless, what is considered to be design tools is fast developing. Architects and architecture students are getting acquainted with technologies used in other disciplines such as engineering, which are keen on the integration of design with the production process. In the last few decades, architecture students have come to experiment with new technologies in their design studios. They are able to construct models out of planes of cardboard pre-designed and pre-cut in the laser cutter according to a production plan. This saves time and provides the desired precision. Alternatively, models can be printed in one-piece solids or in separate solid pieces later put together by the student. More and more, students are also
designing the formwork to produce their unique design elements. They are able to scan and transport information from the hand-made models into the digital medium and mold them into new forms, adapt them to new constraints that emerge during the design process. Additionally, students are knowledgeable in programming, able to quantitatively construct complex parametric designs, represent these in precise virtual models, and to directly instruct prototyping production.

The objectives of production converge on feasibility, efficiency, optimization, and rely on repeated elements. Designers’ effort to grasp, accept, and embrace this methodology is understandable from a practical standpoint in the architectural profession. However, inescapably, the availability of advanced tools in architecture schools transforms the taught conception of the design process to one that is overwhelmed by the goal of production.

If “learning by doing” in the first year design studio is simply getting acquainted with how to do design in general, then “learning design by making” is getting acquainted with how to work with materials towards a product. If one continues this word play, “learning design by digital fabrication,” a more specialized version where digital tools are employed for the act of making, is getting acquainted with working in a particular medium towards a particular product. In this third learning, the making process is invaluably transparent due to the precision required. The hanging question seems to be how the “designerly way of thinking” and design methods are then effected. Is there a divide from “learning design by making” in the first year studio to “learning design by digital fabrication” in the later years?

From the point of view of a first year design educator, if the student is acquainted with the analytical aspect of the digital medium as a part of how to design rather than simply how to produce a design, then there is no divide. This study thus proposes to raise awareness in the first year students regarding the analytical thought processes in design, and shift the focus of value in digital fabrication and digital design from the goal of production to analytical thinking.

4. Learning Design by Analysis and by Computing

The foremost inquiry of the paper is regarding which aspects of design computability can be introduced at the level of the first year. Discussions on this matter have already been ongoing, ranging from how to handle the varying backgrounds of first year students to how to adapt architectural computing to early stages of education (Mark, Martens and Oxman 2003). Here, the framework and the results for strategies tried in a first year design curriculum are described through the examples of two basic design
assignments and the contents of a supplementary course from the first year architecture curriculum at Middle East Technical University.

The approach presented here methodologically emphasizes the analytical modes of design thinking. Rather than the designed products, the student process and experience, as manifested through the documentation they were required to produce in the process, is the subject of investigation to reflect on the learning outcomes.

4.1. BUILDING UP A NEW VOCABULARY

The scope of the course titled Introduction to Information Technologies and Applications expands over various topics from basic knowledge of computer hardware to constructing algorithms. It is currently run in parallel with the design studio and is utilized as a venue to introduce the very basic notions of computation to the first year architecture students. Here only those topics that are directly pertinent to the described studio exercises will be mentioned.

Following a general acquaintance with the basic notions of hardware and software, programming languages, defining variables, procedures and commands, conditional statements, students are introduced to the notion of constructing algorithms. Students first practice constructing algorithms for tasks not related to the design world as they know it. Examples are as general as cake recipes and M Resnick’s LOGO turtle mowing a lawn. These exercises convey the unforgiving aspect of computing that every ingredient must be defined and called upon that definition.

The notion of algorithm is then inquired in relation to the two dimensional compositions assigned in the studio. The question whether it is possible to write an algorithm for a basic design or not is posed. Students are introduced to the concept of visual computing as defined both technically and philosophically by Stiny (2006) in the theory of shape grammars. Three key technical aspects of the theory are discussed: visual rules, part relations and Euclidean transformations. Repetitive exercises of simple visual computations and of determining symmetry groups of various shapes are done in order to grasp ubiquitous part relations and Euclidean transformations. Most importantly, the philosophy behind the theory, in reference to James’ description of reasoning based on the utility of the senses as well as learning, is put to practice by referring students to thinking about visual rules, and part-whole relations in their basic design work.

4.2. BUILDING A LIBRARY OF DESIGN ELEMENTS

Basic design exercises are not as meticulously carried out as, but are very much like, concept design games where certain aspects of the design process are isolated (Habraken and Gross 1988). The isolation draws attention to the
notion that is to be taught. In the series of exercises described below, the abstract, analytical, systematic thinking is recorded and thus isolated as an aspect in grasping design computing.

In the second half of the fall semester of 2005, as part of the basic design curriculum, first year architecture students at Middle East Technical University are assigned the task of a three dimensional composition to be built of planar elements in a duration of two weeks. The student-teacher ratio is 67:5. Initial constraints defined to the students are regarding the use of only two different types of planar shapes, the minimum and maximum numbers of discrete planar elements to be used in the overall design, the minimum and maximum sizes allowed for the finished design, and the use of single material which was cardboard. Students are to come up with two different planar shapes of their choice. The task of producing the pair entails experimentation with possible spatial relations between the two. As students are producing these pairs in numbers out of cardboard, they are asked to develop a library of relations that were tried out and found viable.

Developing a library of relations stands for a categorical documentation of spatial relations physically tried between the elements. Following in principle the practices of shape grammar studios, especially run and discussed by Knight (1999) where spatial relations of a limited number of basic shapes are enumerated to show all possibilities, this exercise differently serves to identify the possible meaning of each selected relation in the context of creating a composition. Stiny (1980) has already pointed out the interaction between the hand and the eye in putting together the blocks in the series of hypothetical Kindergarten exercises to make sense out of the object. Exemplified in the student work similarly but in relation to the composition problem, a possible way to group relations is according to whether they form a defined volume in between the two elements or not. Another one is according to whether a relation is introverted, or extraverted, opening up the edges for new connections with other elements.

For this documentation, orthographic projection drawings are encouraged, whether in pencil or on computer, as a means of abstracting relations and highlighting particular formal properties of the shapes in relation. Each relation is represented in an orthographic set of plan and front side, with alternative second side view. That the elements were planar helps in isolating the faces and the perpendicular edges in relation and how they vary in relation to one another throughout a specified category. For example, in the libraries shown in Figure 1, it is possible to follow how the position of the second element varies in relation to the other, by looking at the lines moving across the planes.

The libraries in Figure 1 represent the typical response of the students to the assignment. Although asked to try out “as many spatial relations as
possible”, students draw mostly an average of eight. Drawing, a task they are not yet very proficient in yet, has proven to be difficult and thus tedious. However, the response received is quite sufficient for discussions in the studio regarding the posed issues.

In the libraries, categories are left entirely to the student to decide. Rather than a goal, the task of categorizing is the means to get the students to think twice about the spatial and formal qualities of the elements and the relations between them.

While students are forming this library of pairs, they are simultaneously expected to work towards organizing a large number of these into a whole. Students are already experienced from the earlier half of the semester regarding strategies in composing, for example, the notions of unity, rhythm, grouping, linear versus central development, etc. The drawn analyses are posed ideally to help students in deciding on organization strategies. For example, a symmetric relation could induce a symmetric composition if it is located centrally, or another volumetric one grouped with two of the same kind could induce a rhythmic element. Works shown in Figure 2 are examples to what the end products of the design task looked like. Nevertheless, this paper puts emphasis on the process illustrated in Figure 1.
The task of forming a library on the side is used in this exercise to emphasize the analytical aspects in design thinking and how analysis feeds synthesis. Considered together with the exercises and discussions in the non-credit course, the representations of spatial relations between the elements of design in the libraries are proposed to manifest the rules of visual and spatial thinking students employ in their designs. As an example, in the photograph that is first from left in Figure 2, the relation of the quarter circle and the square is repeated to achieve a rhythm of twos and threes elements as well as symmetry along the diagonal of the square. Overall this repetition helps the student achieve the unity in the overall composition.

It should be noted that the library in this case does not work as a fixed set of variables as the students learn to define in programming. This difference is emphasized in the discussions in the studio. In the assignment, the design elements are discrete and come together in an additive process of design. Nonetheless they are not fixed in the beginning of the task. The students are instructed that they can add or subtract relations (groups of design elements) from the library.

In the fall of 2006, the same task of working with a library of relations is tried out within the context of a more complex design assignment in the basic design studio with another group of architecture students. On the negative side, the student-teacher ratio is now 80:2. On the positive side, in addition to taking the supplementary course in parallel to the studio, this second group of students has already once before experienced building up a library of design elements within an assignment of creating a three-dimensional composition out of three-dimensional solid elements of five kinds. Before continuing with the case to be discussed, it may be worth mentioning the first experience this group of students has had with forming a library.

In the second half of the semester, students are once again instructed to create libraries while they are working on a three-dimensional composition. This time, the given design elements are three-dimensional solids. Orthographic projection drawings are again encouraged. When the products in the two consecutive years are compared, it is seen that students have been more successful in representing the relations between planar elements than those between three-dimensional ones. Drawing solids in orthographic projection and categorizing them according to formal properties prove to be even more difficult than drawing and analyzing planes. In the light of the results of both years, the success of the students in documenting is connected to a few factors. One of these factors is the complexity of the design elements. Another and possibly the strongest factor is the confidence the students have in doing the task. The task is openly explained to them when the exercise is given out, articulating and emphasizing the role of
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documentation, the format of documentation and how it is expected to reflect to their design thinking. Nevertheless, students may not follow these instructions properly that seem tedious and useless at first.

For the group of 2006, the first attempt to work analytically through a library of relations has not been as successful as in 2005 in terms of the amount of work produced and the effort students seemed to put in. Apart from having the students deal with two dimensional forms as explained as an advantage in the previous paragraph, in 2005, the particular assignment was better synchronized with the topic of visual computation studied in the supplementary course. Nevertheless in 2006 as well, the exercise serves to build up an experience of what was expected from the students for the next time. They are given a second chance at trying the task out, in the final assignment of the semester.

Figure 3. İlkay Güryay illustrates how she derives her design elements on the left, and the final presentation of her library of relations of elements on the right side.

The final assignment is complex in gathering as much of the knowledge and experience they have accumulated throughout the semester. The analytical part described here covers only a small section of the whole assignment that lasted for five weeks. The assessment criteria for the three dimensional compositions to be achieved at the end are formed by each student for his or her project in the first week. The initial task is studying a short story of choice and deriving its five main spaces. The student was expected to interpret the relations of these spaces within the story and represent them spatially in a series of abstract models. In addition to each student’s unique set of criteria thus formed, some of the external criteria for assessment are how much the student is able to carry out a concept between different modes of abstraction and how he or she is utilizing the elements of
design in creating variation in a continuous spatial organization. The three
week process discussed here starts after this stage of establishing the criteria
for assessment.
In this assignment, the task is a three-dimensional volumetric
composition to be constructed out of design elements of two geometric
groups: rigid linear elements and surfaces. As stated in the previous
paragraph, each student derives these elements from a study in the preceding
stage within the same assignment. Once this first attempt at defining the
elements was achieved, the students are once again expected to utilize the
method of constructing a library of relations of elements to help them
proceed with their design. Figures 3 and 4 separately show the processes of
deriving the elements and the final stage of the library by two different
students.

![Figure 4. Seçil Binboğa illustrates how she derives her design elements on the left, and the final presentation of her library of relations on the right side.](image)

These libraries consist of singular elements, pair relations and relations of
larger groups of elements. The means of representation here are not
prescribed to the students, but according to their developed graphic
communication skills, they are able to represent the design elements in
axonometric, or perspective constructions rather than in orthographic
drawings, which have proven to be insufficient for solids. In the case of
establishing categories in the library of relations, the student whose work is
shown in Figure 3 has chosen to keep the point of view in the perspective
drawings consistent throughout the presentation as to be able to compare the
variations between the relations shown.

The many shapes in Figures 3 and 4 only show the elements in the
library. The students were not asked to show the shape computations as they
are not equipped with a formalism such as shape grammars. However with
the assigned task of developing a library of relations, they were guided to
systematically approach design and introduced to computing that is intrinsic
to design. The performed computations would have been clear if the students
were given more time to dwell on and document the relation between their library of elements and the final outcome. Figure 5 gives two other examples to illustrate the varying interpretations of the assignment by the students.

Figure 5. Process drawings by Başak Yüncü and Yasinalp Örsel.

There are also other properties of design elements, which the students feel obliged to represent as they play into the variation of parts. Materials specified in each case are rendered and the types of linear and planar elements are shown separately and in relation to one another.

As mentioned in the previous section, in the supplementary course, the students are introduced to the notion of defining the variables. In the design exercise, they define the variables, but since these are visual, they change from time to time according to changing perception in the changing whole.

Figure 6. Final designs by İlkay Güryay and Seçil Binboğa.

It should be noted here that the libraries represented in Figures 3-5 are the final versions rather than earlier ones, which would have helped to illustrate the process of forming a library. The relations illustrated in these find their way in the final compositions directly. Figure 6 shows two of the final
designs produced in the studio corresponding to the two libraries illustrated in Figures 3 and 4. In both, the relations between the parts of the composition are those described in the libraries. Even if the process is not shown in its full dynamics, where ideally a dynamic library is the tool to test out varying relations towards making a whole, these libraries, snapshots of the very final stage serve to understand the design analytically.

5. Concluding Discussions

This study has been an attempt to draw attention once again to the significance of the “learning by doing” pedagogy for design education, but this time in the changing context of design tools. At a first glance, the pedagogy is seemingly ubiquitously applied given the common studio practice in design education. However when considered in terms of what is being learnt, it is seen that design methods show variance in between different years of education, i.e. between the first year instruction and advanced levels of instruction where digital tools are used. Hence, a way to instruct design as a computation process throughout the years is proposed in order to update the first year curricula of learning by doing.

Recognizing the line of thought that links Dewey’s motto for hands-on education to Stiny’s take on spatial thinking, this paper advocates an understanding of design computing that is thriving on the uncertainties of perception and dynamics of design thinking. Its original contribution is claimed to be in the formulated and experienced process of the students. Following the framework proposed and propagated by Stiny to include the sensorial experience of the subject in computing and referring to Özkar’s previous study (2005), the experimental approach described in this paper aims to develop ways for beginner design students to talk about their design process and thus learn designing as a conscious activity of organizing relations. The students are asked to put emphasis on the analytical activity during very basic design tasks, and are guided in terms of how to document this analytical activity. Using analytical tools such as orthographic drawing are encouraged to capture design rules in visual and spatial ways. Maintaining a balance between analysis and creative hands-on design thinking is deemed imperative.

Learning by doing can be articulated and rephrased in the framework of this paper as both learning design by computing and learning computing by design. Computing is also proposed as the foundation of working with other analytical tools as digital fabrication in later years of education.

In this study three main limitations were observed and left to further explorations in subsequent work. Firstly, the study only focuses on design as composition in the context of the first year curriculum, in an attempt to isolate certain aspects of designing. Secondly, although it dwells on issues of
computation, it does not yet introduce the full use of computers in the first year design studio as it entails social implications as well as being a technical issue as demonstrated by Taşlı-Pektaş and Erkip (2006). Thirdly, it does not yet fully utilize the formalism proposed by the theory of shape grammars. The representations tried out by students are not formal but nonetheless accepted in this study as visual rules. They are supplemented with numerous verbal representations, which may be incorporated into the grammar mathematics through Weight algebras in future work. Allowing for personal narrations as much visually as possible is believed to be a significant step taken at this point.

Another topic to be considered in detail in further research is the student factor. The complex, unpredicted and varying responses of the student body to education presents difficulties in doing research through teaching. For instance, students may refuse to follow instructions if they see it to be useless or too much work for them. Nevertheless, for the comparative thinking that is aimed to be conveyed to them, they need to produce many examples. Here rises the possibility of introducing a tool, for example the computer, to help them enjoy the task and at the same time faster produce what is asked for.

Trying an updated version of ‘learning by doing’ suggestive of systematic thinking in design education in established institutions prove to be difficult. Traditionally the basic design studio is guided by the understanding that the individual is to develop one’s own methods of design through experimenting within the act of creating. Students are mostly expected to create without a given method as they are to develop their own. The general fallback is that a high ratio of students lacks confidence upon feeling unable or not gifted. Moreover, the curriculum lacks other supplementary courses that would serve the studio in terms of teaching the contemporary context of architectural design in relation with the tools the technologies have to offer. The methodology in education that is tried here is the introduction of guidance to learning by doing in the age of design computing. The assignments described are attempts to negotiate between the traditionally tested methods of design teaching and the futuristic models, and to indicate the possibility of change without much compromise. In spite of this optimistic standpoint, it is the personal position of the author that required courses supplementary to the first year design studio should be fast updated to introduce the contemporary context of architectural design and the contemporary status of design tools available. Clinging to hopes of timeless values may just be currently debilitating design education. Educators should learn from the past as well as from the future to update their outlook on design.
Acknowledgements

The author would like to acknowledge Selahattin Önür, Tuğyan Aytac Dural, Nihal Bursa, Nicolai Steino, Derin İnan, Başak Uçar, Pelin Yonca in reference to the preparation and execution of the design exercises, and Arzu Gönenç Sorguç in reference to the preparation and coordination of the non-credit course.

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