Computer Simulation as an Integral Part of Digital Design Education in Architecture

The Modulator

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Abstract. It has been more than a decade that the first discussions on the integration of computational technologies into architectural education, especially into the design studios have been started. Since then, the use of CAD from drafting to complex solid modeling and manufacturing in design studios has been mostly achieved. Yet, persisting on the discussions within the same context, mostly focusing on the studio education and CAD/CAM rather than “CAAD” avoids inquiring other potentials of them as being a learning and implementation media of different knowledge domains. In this context this papers presents a discussion on andragogic learning by the integration of simulation technologies to architectural education to synthesize the fragmented knowledge that provides new learning media.

Keywords. Computer simulation, digital design, architectural education, modeling, modulator.

A GENERAL PERSPECTIVE ON THE MODES OF LEARNING/TEACHING AND TECHNOLOGY AND ARCHITECTURAL DESIGN EDUCATION: TEACHING DESIGN TO ADULTS

The undeniable impact of information and computational technologies in every field of life, massive amount of “information and/or knowledge” production and consumption (re)describes the disciplines and their methods, introduces new fields of interests, possibility of enormous data handling and number crunching which eventually force to re-define what knowledge literacy is and how the learning (and thus teaching) should be revised. Consequently the effects of these technologies on the education deserve more consideration of anyone who is an actor of this process, not only of the education technologists and researchers.

Today it is acknowledged that one of the major problems in education is to teach how to select and read “knowledge (and information) produced in bulks. Therefore, the importance of “design of education” or as it is generally termed “instructional design”
has been more emphasized resulting in the evolution of curricula in which technology is an integral part of it.

In this transformation, the learner profile (adult rather than child) in the university education should be well accredited in order to propose appropriate educational methodologies. One of the foremost figures of modern educational theories, Knowles (1977) described the major characteristics of adult learners and principles of “andragogy” as;

“(i)...their selfconcept moves from dependence to self direction, (ii) their growing reservoir of experience begins to serve as a resource for learning, (iii) their readiness to learn becomes oriented…”

Learning strategies developed based on the andragogy are centered on the following assumptions as (Bangaoil 2011);

“...the need to know why something should be learnt, the need to learn by experiencing, the conception of learning as a problem solving activity, the influence of priority of the subject matter on learning…”

The learner centered andragogic model describes the learning process composed of four main phases: experiencing, processing (reflective observations), generalizing (abstract conceptualizing), and applying (active experimenters). Kolb and Boyatzis [1] explain the main characteristic of the learning cycle as;

“...Experiencing (Concrete experiences): Adults have a receptive, experience-based approach to learning, rely heavily on feeling-based judgments, learn best from specific examples and discussions; Processing (Reflective Observation): Adults rely on careful observation and learning best from situations allowing, impartial observation; Generalizing (Abstract Conceptualization): Adults learn best from impersonal situations, from the opportunity to integrate new things with what is already known, and from theory; Applying (Active Experimenters): Approach learning pragmatically, Rely heavily on experimentation and learn best from projects…”

Upon principles of andragogy and the acknowledgement of the learning cycle, several studies on instructional design, have been conducted giving way to develop new learning and teaching theories. Disciplines are in the search of their own methodologies appropriate for their knowledge domains. Andragogic model also re-defines the role of educator as being a facilitator rather than a teacher organizing/designing the process of learning when the adults are concerned.

Another important outcome of andragogic model, for which problems matter more than subjects, is the integration of instructional technologies relying on the use of hardware and/or software to the learning/teaching activities in all the levels of education. Today, complex LMS (learning management system) and simulations customized for the disciplines involve and evolve education starting from the primary school to university and then to life-long education.

Any design process which compromises inspiration intuition and cognition requires not only the incorporation of diverse knowledge domains but also development of the “process architecture”, allowing complex relations and feedbacks to achieve the required design goals and performance. This complexity of the design process necessitates an educational model responding to the specific requirements of the domain.

Architectural design which has been continuously transforming with computational and informational technologies compels architectural education more than ever to develop methodologies allowing handling this “new level of complexity”. In this context, understanding andragogic principles and the learner profile as defined appears to be promising.
ARCHITECTURAL DESIGN EDUCATION AND COMPUTATIONAL DESIGN PARADIGM

Architectural design requires both artistic skills and scientific and theoretical/academic knowledge that students needed to be backed up with relevant courses. It is a common observation that students have some difficulties to incorporate and/or process their knowledge attained in the complementary courses of their education into design studios. It can be claimed that “...the more concrete the example, the more effective the learning...” (Dale, 1969) would be achieved as a common learning/teaching strategy.

In this point of view providing the learners an environment in which real experience is happening, gives them an ability to experiment and learn from the results of their decisions. The level of similarity of the simulated experience to the real-world experience will influence the power of this effect/impact. Simulations and simulation programs has a potential to be used repetitively with different outcomes focusing on the similar learning goals economically and without risky and consequence consolidate the learning process and/or help learners discover their own gaps within the context of what they need to know. From this context, this paper, first, inquires the potentials of simulation software and CAAD as a learning environment.

Simulation programs developed for analysis of specific problems like acoustics, structure, thermal conditions, fluid mechanics and etc. requiring certain expertise in the field of interest, deserve more consideration in architectural education as tools to incorporate different knowledge fields provided in the bulk of education into design studios. Typical analysis software used in architecture, in relation with performance and behavior of the buildings require solid models developed in CAD media to which students feel themselves close. Besides, the techno-skills of students also allow them to use these analysis/simulation programs intentionally or “instinctively” enabling them to get “some data” which is mostly “unreadable” due to compartmented knowledge and lack of “domain knowledge literacy” which should be developed by/during the education in the discipline. Then it is worth to re-investigate such programs which provide an interface to which students are very familiar with yet requiring having ability to incorporate their developing knowledge into design.

Algorithmic thinking with the invent of modern computers has been first re-structured in the first computer programs then in the course of time they generate software architectures embracing different levels of complexities and information through diverse number of interfaces developed for the end-users. In this sense, simulation software with their multi-disciplinarily in their nature, both in terms of their design and in terms of their use as they can be considered as means forcing end-users to shift their minds and develop ability to use the whole body of their knowledge i.e. knowledge literacy.

In this context, understanding the contemporary simulation programs and their “architecture” is worth to further extend the use of computational technologies in architectural education. Here, a general taxonomy of typical simulation software used in architecture is presented in order to further illustrate how these softwares determine the design process and process of learning (Table 1).

| Table 1 |
| Common simulation software used in architecture |

<table>
<thead>
<tr>
<th>CAD</th>
<th>(Visualization Representation)</th>
</tr>
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<tbody>
<tr>
<td>ArchiCad</td>
<td>Revit</td>
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<tr>
<td>AutoCad</td>
<td>Maya</td>
</tr>
<tr>
<td>Google Sketch Up</td>
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<tr>
<th>CAM</th>
<th>(Visualization Manufacturing)</th>
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<tbody>
<tr>
<td>CNC</td>
<td>(CNC Syntax, Solid Cam Mastercam, ProgeCAD...)</td>
</tr>
<tr>
<td>NX CAM</td>
<td>Diskates</td>
</tr>
<tr>
<td>Desktop</td>
<td>Solid EDGE</td>
</tr>
<tr>
<td>Solid Concepts</td>
<td>Axify</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HVAC</th>
<th>(DOE-2, AUDIT, HVAC Solution, HVAC Tools, Ventilation Tools, SHADOW...)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Acoustics &amp;Noise Control</td>
<td>(Odeon, Catt Acoustics, Inslul, Zona, ENE, CARA, Room EQ, SpectraPLUS...)</td>
</tr>
<tr>
<td>Structure</td>
<td>(Sap2000, ANSYS, Nastran, STRUDL, ...)</td>
</tr>
</tbody>
</table>

| Lighting | (Lighting 4D, Dialed, LightCalc, SPEDS...) |

<table>
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<tr>
<th>Architectural Design</th>
<th>(CAAD) Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasshopper</td>
<td>Rhino</td>
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<tr>
<td>Cura</td>
<td>Carpa</td>
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</table>
The general features of present simulation software(s) with their numerous libraries, various data transfer means from one domain to another, with complex and yet “user-friendly” interfaces have many potentials to provide means required to teach novice architecture students and even the professionals through the “models” they developed. The idea of model in this paper has been used in two-folds: as a computational model to represent the problematic (Figure 1) and then solid model as the input for the simulation which necessitates different level of knowledge and expertise as well as depending on the subject of interest. The modelling cycle of computational design exhibits a strong resemblance with learning cycle as shown in Figure 1.

It is necessary to point out that starting with first object oriented programming, interfaces have been displaying similarities, and consequently, end-users have been easily adopting themselves to these interfaces. Beside those generic features of these programs, the possibility of customization of their use at some extend by the end-users allow the use of these tools by various disciplines. Hence, regarding the current levels of software technology and especially simulation programs and their usability, discussions related with integration and customization of computational technologies in architectural education should be continued together with the explorations of the potentials of such technologies in architectural education.

There exists various simulation programs fulfilling the same or very similar tasks, having similar interfaces in interacting with the user, just having different in terminology/concept in relation with the field of expertise. Thus as it is discussed previously the similarities in the interfaces enable end-users to have some general constructs in any interface and ability to use them accordingly. This can be regarded as an opportunity in teaching: having a user-friendly interface to explore complex subjects.

**AS A CASE: THE MODULATOR**

In the case of architectural education, using simulations on the design model which is developed in one of the modeling media and then translated into analysis/simulation environment, offers students to incorporate their knowledge. Learning structure, discussing acoustics or experiencing thermal comfort from the very beginning of design process also encourage students to integrate design studio with complementary courses in the curriculum, then to be acquainted with multi-disciplinary approaches and collaboration with other disciplines.

In the light of the discussions above, finally, this paper exemplifies the process through one of the fourth year computational design studio studies, namely the design of “Modulator” (Figure 2). The design process and how the simulations affect the design process and improve the design skills and knowledge of students have been exemplified.
The term project named as modulator is one of the assignments of the fourth year digital design studio focused on computational design and performance based architecture in METU Department of Architecture [3]. Initially ill-defined design problematic aimed students to define the problem its requirements, identification and definition of variables and parameters and most of all knowledge domains to be integrated then the development of the design process from virtual to physical.

The overall performance of the design was asked to be (re)evaluated in every phase of the design process. This forced students to develop skills to incorporate different knowledge domains and to read and implement the data within the design process containing several feedback and feed forward relations among the different phases of the design as well as information/knowledge (re)produced and (re)implemented. In this iterative process, several modes of simulations took place, allowing students as adult learners, to experience the problem through model generations (simulation of the abstract ideas), enabling to process the information and knowledge through simulations (exposing their knowledge domains through simulations), generalization (feeding back their experience gained in the simulations) and applying (end product and new designs).

In the modulator experience, simulations are not only the media of integration of knowledge and/or information; but also learning environments (medium) which responds the requirements of andragogic approach. During the design and manufacturing process of the modulator, three modeling program in digital medium and three modeling and manufacturing techniques in physical environment were experienced. Each tool/medium was used/served for different purposes. At the beginning there was a need for better definition of reference curves. Although for optimization of 3D model and materialization processes, Rhino with Grasshopper interface was used primarily for parametric design purposes (i.e. deciding in number, thickness, spaces...
and frequency of ribs and slices), Google Sketch Up program was used for quick estimate and visualization, SAP for structural analysis, and AutoCAD for precision of the nesting work. During the process, rapid prototyping model and laser cut models contributed significantly to make decisions on construction sequence and ease of manufacturing and construction as well as visualization, materialization and determination of structurally critical points on the models. Throughout the semester, students used different design and modeling tools and media, some of which were very familiar to the students; however, some others were very new. In this process, they learned and developed their Grasshopper knowledge, and they produced rapid prototype and laser-cut models and had the pieces by water jet for the first time. For each modeling/manufacturing process, they had to learn rules and precision of the machines as well as features of the materials to be used.

The structure of the design process shown in Figure 3, demonstrates how information/knowledge have been integrated in each level. In this iterative agile model of the design, simulations software can be considered as agents for the “knowledge literacy” and dissemination of the knowledge.
CONCLUSIONS AND FURTHER REMARKS

In this paper, it is aimed to discuss the use of simulation technologies as a part of architectural education. The accentuated trans-disciplinarity of architecture and the growing complexity of the design process with the technology forces architectural education to find new media to compete with those requirements of the digital age. Simulation technologies in this context offer potentials to integrate knowledge into design process but also a media to teach and learn in an interactive way, where problem matters more than subject which facilitates learning as andragogy principles describe.

Hence their use by the adults in problem oriented way provides a broad learning environment, allowing the synthesis of diverse knowledge/information in a very structured way. Therefore knowledge literacy and incorporating what is learnt have been achieved by the use of them. As a consequence the use of several simulation technologies and software provide a media of learning and overcome the compartmentation of knowledge.

REFERENCES


