THE USE OF BUILDING PERFORMANCE SIMULATION TOOLS IN UNDERGRADUATE PROGRAM COURSE TRAINING

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ABSTRACT

Not only in building construction industry, but also in engineering and architectural education the use of simulation tools has a great interest. Rapid advances in the capabilities of simulation tools and computer technologies have provided additional potential and choices for the designers and trainers. There are several kinds of simulation tools for energy efficiency and daylighting. During training practitioners, use some of them. This paper aims to discuss if there is any way to define and compare which one is appropriate for different stages of design process. Some of them are very complicated; on the other hand, some of them are much unsophisticated and not verified.

The authors provide experiences of two workshops to show how the simulation tools successfully used to train the students. In addition, guidelines provided to maximize the usefulness of simulation for training student skills in sustainable design.

INTRODUCTION

Architectural design became more complex and facing enormous technological and institutional transformations. The profession of architecture and its position in the construction and property industry has changed dramatically in accordance with the emerging and fast growing needs of construction industry such as enhancing sustainability, greater client sensitivity and responsiveness, more effective cross-disciplinary collaboration amongst industry professions (Nicol& Pilling, 2000). In parallel to the architectural practice, the integration of sustainability and green energy technologies into architectural education is required to train future generations of professionals in design and construction. It is relevant to say that, technological changes and society's demand for a more sustainable environment reshape architectural education. The profound interest towards designing energy conscious and ecological buildings to reduce global warming effects has exacerbated the demand for introducing new generations of architects to the principles and practices of environmental sustainable design. With the help of rapid advances in both computing and engineering, various simulation tools have produced to evaluate building performance in the early design stage. The use of these simulation tools makes the architects to analyse and evaluate their own design decisions instead of engineers who are mostly get involved late in the design process. By this way, the architects could retrieve their important role as a leader of design team.

In achieving high performance buildings, the utilization of these tools throughout the architectural practice and education has an essential importance. To introduce how dynamic environmental forces and ecological processes can inform design thinking and strategies, many architectural design faculties have attempted to integrate environmental comfort and building physics theories with design studio focusing on energy efficiency and daylighting issues. The integration approach including learning objectives, methods, and tools fosters greater understanding of architecture within a dynamic, responsive, and adaptive ecological context (Guzowski M. 2013).

Enhancing students' capability in solving design problems creatively and constructively through project based-learning maintains the core of the architecture education. Simulation of practice, mimicking the real world design projects is a way of project-based learning, where learning is student oriented and case based. In this approach, the student understands the problem solving process and learns to use information for a specific purpose. Developing student's design knowledge and skills achieved by learning by doing (Göçer, 2015). In mimicking the real world design projects, various simulation tools are required to visualize and evaluate design solutions. Utilization of these tools throughout the architectural education can provide a better understanding and visualizing of building performance. The integration of simulation tools into the design process in an ongoing discussion actively targeted in architecture education (Delbin et al., 2006). Simulation is inarguably a powerful training tool due to have the advantages of systematically control the schedule of practice, presentation of feedback, and easy to apply then the predictive methods.

In contrast, given the breadth of choices of building performance simulation (BPS) tools, it has become a challenge for trainers to select the appropriate one in training process. The BPS tools are mainly restricted to the final stages of the overall building design process, but instructors and also students need early stage, strategic design decision support tools. Some of these tools are very complicated; on the other hand, some of them are much unsophisticated and not verified. This paper presents a selection method to define and compare which simulation tool is appropriate for different stages of design process. In addition, the experiences during daylighting and energy efficient designing workshops shared to discuss which of these programs are appropriate for level of undergraduate students, from the viewpoint of theoretical background requirements, user-friendly interface and visualization capability.

THE NEW REQUIREMENTS OF ARCHITECTURAL EDUCATION

Architecture is not only a design profession, but also a field of science and art. So this makes architectural education more complicated than it seems. The challange of architectural education is find the way of helping the designers to develop skills in design problem-solving and use relevant prior knowledge to solve new design problems. (Hernan C., & Goldschmidt G. 1999)

The influence of ongoing development in the construction industy makes it more difficult to cope with the new advances and technologies. Because of that, architecture schools need to reform architectural education according to the new demands of construction industry and society. They revise their program contents and curricula and have begin to take sustainable design approach into account. In 1996, UIA and UNESCO created The Charter For Architectural Education in order to ensure the understanding that architectural education constitutes both the sociocultural and professional challenge of the contemporary world. The principle of ecologically balanced and sustainable development of the built environment has been included as a goal in the vision of the architectural schools (Ceylan S. 2014).

According to the European Parliament and the Council (2005) the architectural training is defined as ―training, which must be of university level, and of which architecture is the principal component, must maintain a balance between theoretical and practical aspects of architectural training. UIA (2009) determined the objectives of architectural education ―to develop the capacity in students to be able to conceptualize, design, understand and realize the act of building within a context of the practice of architecture which balances the tensions between emotion, reason and intuition, and which gives physical form to the need of society and the individual‖. National Architectural Accreditation Board (NAAB) of USA, in the 2004 accreditation conditions, lists 33 headings that a graduate student must demonstrate understanding or ability for the purpose of accreditation of a school (NAAB, 2004). Turkish Architectural Accreditation Board (MĠAK-Mimarlık Akreditasyon Kurulu) defines similar knowledge and skill headings within 2007 Accreditation Conditions (MĠAK, 2009) similar to the items defined in NAAB 2004 conditions. Among these subjects the following article relate this study as; adequate knowledge of physical problems and technologies and the function of buildings so as to provide them with internal conditions of comfort and protection against the climate.

The building technology as a strong supporter to architectural design is the key element to achieve the innovation in the architectural education to achieve the related current issues, such as energy efficiency and user comfort. The building technology courses are still based on knowledge transfer teaching methods with the lack of new innovative and computer based training methods. This may greatly upon the practitioners less interface with new simulation programs and the scarcity on the relevant simple but comprehensive simulation tool in building technology education.

In order to keep pace with the stringent demands of Architecture, Engineering and Construction (AEC) industry, students need to be trained by flexible programmes which can be provided with complementary and elective courses, and workshops which support design courses. But although simulation is inarguably a powerful training tool, we still don't have a magic one tool that can meet all our needs. To design solution alternatives to meet the problems of massing, orientation, shading, natural ventilation, glazing etc which are relevant questions for preliminary building design, students need to have the capability of using different drawing and simulation tools. The students are expected to use efficiently some of the following tools during their training period;

- Drawing tools such as AutoCAD, AllPlan, ArchiCAD, Skecth up etc.;
- Drawing tools enables creating non-euclidean geometries and parametric design such as Rhino, Grasshoper etc.
- Rendering and animation tools such as 3D Max, 3D Studio etc,
- Building energy performance simulation tools such as Ecotect, Energy10 etc.,
- Daylighting simulation tools such as Velux, Relux, Radiance etc.,
- Atrificial lighting simulation tools such as Diva, DialuxEvo Evo.
- Urban scale simulation tools such as SIMlab, GIS etc.,
- Landscaping design tools such as Lumion, IScape etc.,
- Architectural design project presentation tools such as Photoshop, Indesign etc.

The programs which cover any of the two items in above at the same time comes to further in instructors or students priority list, such as Revit.

For the success of a student design project, students should have higher capability of using not only drawing tools, but also one of these building simulation tools. But this is not enough to produce and present a design project successfully, they should manage complex information sharing procedures between these different tools. Because, there is no full software interoperability as few simulation tools support the link between the geometric information contained in CAD drawings and non-geometric information about the objects that they represent. Different tools use different building concepts and context representation (Delbin et al., 2006). To create for non-euclidean or parametric geometries, sometimes CAD programs can be inadequate. Since heavy work loads and excessive running time of programs, students disincline and feel exhausted in the first weeks of the course.

To encourage the students, especially in the first two years of the program, to use these tools, the ideal simulation software should

- be easy to understand; user firendly,
- export geometric data from different drawing tools,
- not require detailed input data such as building material, weather file, etc.
- give comparative analysis for the question "what if"
- not require complicated hardware
- enable simple modifications on the building model

METHODOLOGY

Overview

The main objective of the research is to analyse the role of computational models in the architectural education. Specifically, the study mainly involves three simulation models in the design evaluation in bachelor level courses.

A number of 21 second-year undergraduate students from Ozyegin University, Faculty of Architecture were selected for the present study (Table 1). They participated in detailed questionnaire-based interviews (conducted in winter and summer workshop, 2014-2015). The workshop mainly involved the application of the simulation software (Ecotect, DialuxEvo) in the design process.

Table 1. Questionnaire's main items

i.	The workshop met my learning needs
ii.	I found the workshop relevant to my stage of learning
iii.	This workshop will impact on my project approach positively
iv.	The content was designed correctly
v.	My theoretical background was adequate to follow the workshop
vi.	The number of participants was adequate
vii.	Duration was adequate
viii.	I can easily create geometries (euclidean)
ix.	I can easily create geometries (non-euclidean)
x.	I can easily upload geometries created with other drawing programs such as Rhino, CAD
xi.	The material library of the program was adequate
xii.	I can understand properly the steps of the process
xiii.	I can follow instructor-the interface of the program was user friendly
xiv.	I can easily create/install environmental data for my Project site
xv.	I can easily create visual output data
xvi.	The program allows creating output data for other simulation programs
xvii.	Usability and Graphical Visualization of the Interface
xviii.	Accuracy of the tools
xix.	Most important features of a simulation tool: user friendly
xx.	Most important features of a simulation tool:3D visualization of design strategies
xxi.	Most important features of a simulation tool: Graphical representation of design parameters
xxii.	Most important features of a simulation tool: building input database
xxiii.	Most important features of a simulation tool: Balance between extensive (deep) and quickly (basic) input data
xxiv.	Most important features of a simulation tool: Ability to add/remove building features with ease

Model selection

The workshops were organized in two sections for second-year undergraduate students to generate and prioritize ideas for next-generation simulation environments where the scope was simulation of natural/artificial daylighting and basic design and passive techniques for energy conservation.

The second-year undergraduate students' capabilities considering the requirements of these workshops can be listed as;

- have the experience of conceptual design projects
- have the knowledge of building materials and construction, but not about the environmental control course yet.
- can use architectural drawing tools, such as AutoCAD and Rhino.

Each workshop was organized in four breakout sessions: Basic Theory of Natural/Artificial Lighting; and Passive Energy Systems and Methodologies; Applications, Presentations; Feed Back.

To explore the impact of the computational building models, two programs were introduced in two extensive workshops DialuxEvo (winter term 2014), Ecotect (spring term 2015). The selection criteria are based on the easy and friendly use and graphic representation of the models. As such, the relevant use of the simulation programs in the design stage of the architectural education could be implied and potentially improve the design. Due to the limited capabilities of the second-year undergraduate students, some features such as complex geometries and import from other programs were not highly considered in the design stage, focusing mainly on the simplification and concept based approach.

- DialuxEvo is simulation artificial planning software including latest luminaire data of different manufacturers, including indoor and outdoor spaces.
- Ecotect is an environmental simulation tool that evaluates the performance of the building in different stages of the design. It integrates functions with an interactive display and presents results analytically within the context of the building model.

RESULTS

Based on the responses to the questions in Table 1 Table 2 to 5 show the main interview results for the "non-users". The questions were based on a five-point Likert scale. The mean in the tables shows the place of the answers in that scale.

Table 2. Questionnaire's Results (1-6 questions)

		Q.1	Q.2	Q.3	Q.4	Q.5	Q.6
Ecotect Nr: of surveys:12	Mean	3.8	4.0	3.8	3.8	3.5	3.8
	%	75.0	80.0	75.0	75.0	70.0	75.0
	Std. Dev	0.8	0.9	1.1	0.9	0.9	1.1
DialuxEvo Nr: of surveys:9	Mean	3.8	4.0	3.8	4.3	3.8	3.5
	%	76.7	80.0	76.7	86.7	76.7	70.0
	Std. Dev.	0.8	0.0	1.0	0.5	1.0	0.8

Table 3. Questionnaire's Results (7-12 questions)

		Q.7	Q.8	Q.9	Q.10	Q.11	Q.12
Ecotect Nr: of surveys:12	Mean	3.7	3.7	2.8	3.1	3.3	3.5
	%	73.3	74.5	56.7	61.7	66.7	70.0
	Std. Dev	0.7	1.3	1.3	1.3	0.7	0.9
DialuxEvo Nr: of surveys:9	Mean	3.8	4.1	3.1	4.1	3.1	4.1
	%	76.7	82.2	62.2	82.2	62.2	82.2
	Std. Dev.	0.8	0.6	1.2	0.8	0.3	0.6

Table 4. Questionnaire's Results (13-18 questions)

		Q.13	Q.14	Q.15	Q.16	Q.17	Q.18
Ecotect Nr: of survey s:12	Mean	3.8	3.3	3.6	3.6	3.8	3.6
	%	76.7	66.7	71.7	72.0	76.0	72.0
	Std. Dev	1.3	1.2	0.7	0.7	1.1	0.5
Dialux Evo Nr: of survey s:9	Mean	4.0	3.6	3.6	3.2	4.0	3.6
	%	80.0	71.1	71.1	64.4	80.0	72.5
	Std. Dev.	0.7	1.0	1.1	0.7	0.0	0.5

DISCUSSION

The review of the responses of the questionnaires leads to a number of observations:

- While the overwhelming majority of architectural students use general CAD tools, BPSTs are not used (only in specific workshops). Moreover, the use of BPSTs is limited to the light simulation (Velux, Relux)
- More than 80% of the users found relevant the use of the simulation program in the design stage. 75% of the results show that the workshop of introducing the simulation programs will improve their design.
- However, based on the results the students found limited some features of the simulation programs such as limitation in creating complex geometries, as well as importing geometries from other CAAD programs (CAD, Rhino), 56% for Ecotect, 62% for DialuxEvo respectively.
- In terms of the usage of the program the users expressed limitations. The material library of the Ecotect program was found limited (66% of the responses answered positively), followed by DialuxEvo (62%). The steps of the process in general were not perceived well, for all the programs. A reason could be the limited experience on the usage of the simulation programs. Ecotect was found to be the most difficult program to understand properly the steps of the process (70% of the results).
- When students were asked to select the most important feature of a simulation tools, the

students answered that the most important feature of a simulation tool for the Ecotect was the graphical representation of design parameters (83%), for DialuxEvo was a user-friendly program (82%) (Figure 1.).

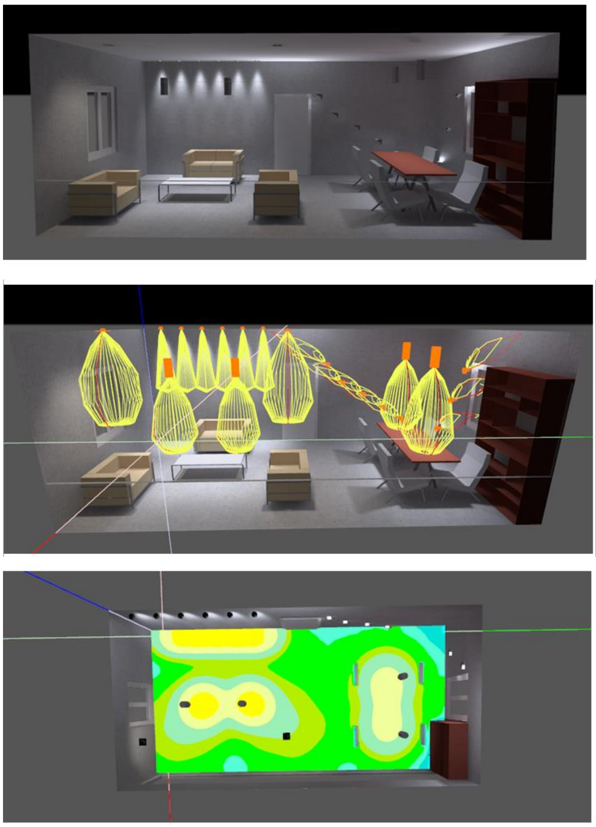

Figure 1. The artificial light analysis of a student's project with DialuxEvo

Table 5. Questionnaire's Results (19-24 questions)

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		Q.19	Q.20	Q.21	Q.22	Q.23	Q.24
Ecotect Nr: of surveys:12	Mean	3.8	4.0	4.2	3.9	3.0	3.6
	%	76.4	80.0	83.3	78.0	60.0	71.7
	Std. Dev	1.3	1.3	0.7	0.7	1.0	1.2
DialuxEvo Nr: of surveys:9	Mean	4.1	3.9	3.7	3.6	3.3	3.7
	%	82.2	77.8	73.3	71.4	66.7	73.3
	Std. Dev.	0.6	1.1	1.0	0.8	0.9	1.2

CONCLUSION

Many of the current simulation and modelling tools were developed to measure a single or a few specific criteria, since existing building physics and building systems complex interactions, which are very difficult to capture and represent. As such, undergraduate students find simulation tools hard to understand the theoretical background behind them. In conceptual design, the tools, which allow comparative analysis of building model alternatives with unsophisticated knowledge, are required in training especially first two-year level students.

A considerable fraction of the students perceived well the role of the building physics and performance assessment as integral to their design process. They seem to believe that such tasks should be "insourced" by them instead by other building physics "experts". As such, this view is positive, because not only it opens a further window of professional competence on the side of architects, but also because it improves the preliminary stage of design (with its importance for the performance) with the benefit of timely performance analysis feedback such as in the early design stage performance. Thus, efforts to popularize building performance assessment (and the respective tools) in the design development phase should be encouraged.

The immediate next step that the research team is going to take is to propose a selection method for the use of simulation tools to train the students from different graduate levels. In addition, guidelines will be provided to maximize the usefulness of simulation for training student skills in sustainable design.

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