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Integration of daylighting simulation software in architectural education

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Abstract

This paper reports on an academic experiment, in which simulation software were successfully integrated in the teaching of daylighting in a building sciences course. It was conducted on undergraduate architecture students at the American University in Cairo, Egypt. The software Ecotect and Radiance were used. A survey was given out before students engaged with the software, and then interviews and another survey were conducted after complete engagement with the software to test their knowledge about daylighting. Output of this experiment demonstrated that teaching daylighting science was significantly improved by the visual engagement that was offered by the simulation software. Students recognized the positive impact of the computer software on their education. They also displayed an understanding of when and how to integrate them at various stages of their design process. However, they showed that they were not aware of how to utilize the software for more complex designs unless assisted, and that the integration did not affect their positive perception of building sciences and its importance. Conclusions were drawn and recommendations were stated.

Keywords: daylighting, education, architecture, simulation, computer-aided-learning

1 Introduction

The education of future architects should equip them with the necessary tools for utilizing available natural energy resources. This would reduce energy consumption, and aid in the reduction of carbon emissions among other benefits. Utilization of natural light in internal spaces of buildings creates large energy savings and provides a productive atmosphere for users. The training of undergraduate architects on the utilization of daylighting in buildings in Egypt is almost totally dependent on abstract scientific lecture format that is difficult for students to perceive. It depends on the “Direct Instruction” approach to learning, which suits the transfer of basic knowledge. This results in a separation between lecture topics and design studio application. Most of the graduates of this system fail to fully integrate daylighting in their design, thus waste a large potential energy saving. Simulation software tools could help in this respect by assisting students in taking a grasp of such a visual science. They allow students to quickly experiment with design alternatives, thus identifying the consequences of design decisions on daylighting performance. Earlier attempts by one of the authors in introducing Computer-Aided-Learning (CAL) software tools to the education of undergraduate students proved to be successful (Sherif and Mekkawi 2008).

Previous research either reported on methodologies of teaching daylighting or investigated the integration of building performance simulation software into architecture education. Significant publications in the last decade concerned specifically with the education of daylighting included a procedure that helped architecture students to visualize, further develop, and comprehensively understand the performance of their daylighting designs (Mansy, 2004). Also, a teaching method used in the lighting section of a design studio was previously illustrated. It included examples of projects achieved during the studio (Dubois, 2006). Other research that introduced the integration of daylighting simulation software into architectural education includes an evaluation of the integration of Ecotect, an environmental prediction software package, into teaching within Welsh's school of architecture (Roberts and March, 2001). This research stated that the software proved a potential benefit for improving student understanding of concepts that often remain in the domain of lecture theatre theory so that they can be applied to student design work as a whole. It was based on comparing students' work in physical modelling and simulation in regards to shading patterns.

Other related publications in regards to building performance simulation and education concentrated on the integration of simulation software within a collaborative/ multidisciplinary higher-education environment. One research presented a semester-long setup in which a course was jointly taught by an architect and an engineer and attended by both architecture and engineering students. It ultimately aimed at collaborating with an undergraduate architecture design studio on proposing upgrades to an existing building (Charles and Thomas, 2009). Another research aimed at looking into the insight of how higher learning institutions are keeping up with equipping their graduates with the right CAD applications that are actually being used by architecture firms (Mohd-Nor 2009).

This paper reports on an experiment in which professional simulation software tools were successfully integrated in the teaching of a daylighting course to undergraduate architecture students at the American University in Cairo, Egypt. The course is part of a new program that aims at promoting the implementation of information and communication technology in architecture, while incorporating construction engineering and professional contents which respond to the needs of the industry (Sherif et al 2008).

The paper is divided into two parts. The first part: the academic course's approach to daylighting education is explained, with focus on the course project in which the simulation software was utilized. The second part: assessment method of evaluating the impact of using such software is described and results are stated, followed by a detailed analysis of the research findings. A discussion was drawn to be concluded with potentials, limitations and recommendations for further research.

2 Academic approach to daylighting education

Teaching of daylighting science and its relevance to architecture is a part of the undergraduate academic building sciences course. The primary aim of this course is to define the concepts of environmental control and energy conservation, while emphasising their influence on the design of the built environment. This will consequently reflect on architectural design for human needs, comfort, spatial performance and users' well-being. Appropriate daylighting strategies have a significant share in realizing this aim. Fundamentals of daylighting were introduced along with their relevance to building design. Quantitative and qualitative analysis techniques of different daylighting situations were also defined. In addition, diverse methods of assessment such as on-site visual investigation, calculations, computer simulations and advanced daylighting systems utilization were presented in this course (Figure 1). Generally, the "lighting" part of the course had the clear objective of providing the tools necessary for an efficient integration of daylighting strategies in the building design process and incorporation of artificial lighting control systems.

2.1 *Teaching of daylighting*

The next part is a description of the expected learning outcomes of the course and the methods utilized in the teaching of daylighting as a building science.

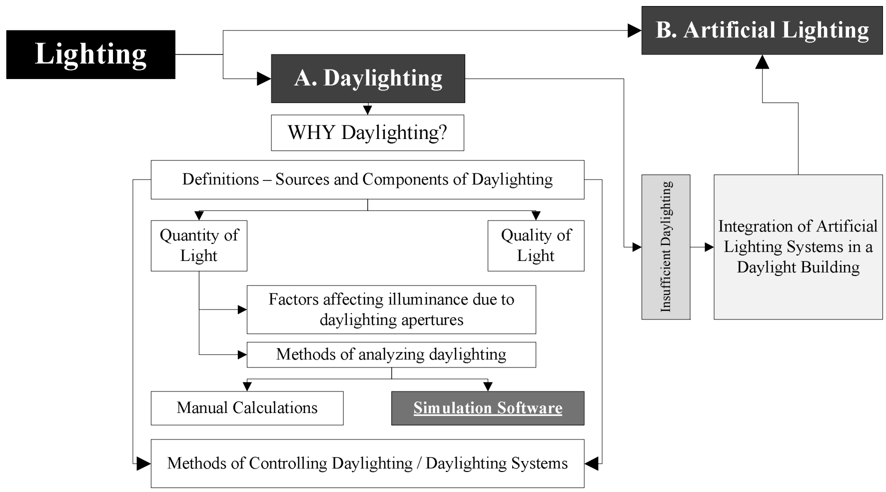


Figure 1. Academic approach to teaching lighting

2.1.1 Learning outcomes

At the end of the daylighting course, students should be able to understand the role of daylighting in designing environmentally sustainable buildings and explore the benefits and challenges of utilizing daylighting in designs. They should also have acquired the ability to understand the methods of analyzing daylighting and their impact on the decision-making and the design process of buildings and engage in effective communication strategies, while working in teamwork, to solve interesting problems by enhancing daylighting performance.

2.1.2 Learning methods

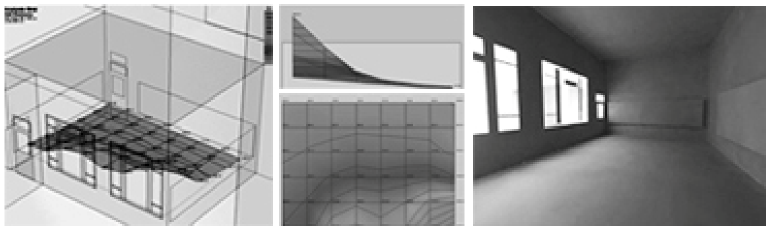
In order to ensure that students fully understood lectured daylighting theories and that they were able to predict daylighting performance in indoor spaces, two methods of analysis were utilized: manual calculation methods and computer simulation analysis. This paper is only reporting the experience of integrating daylighting simulation software into the education process. This experience had two objectives, the first was to improve students' ability to properly interpret and analyze analytical results produced by computer simulation tools. The second was to identify the techniques and systems that enhance daylighting performance in existing indoor spaces. The software Radiance and Ecotect were used. Radiance emphasizes the quantification of the lighting/daylighting luminous interior environment, such as daylight factors, illuminance distributions and visual comfort assessment. It also allows students to examine the quality of daylight of different design strategies by rendering qualitative images that analyze glare and daylight distribution (Ward and Shakespeare 1998).

2.2 *Simulation project*

To ensure that students understood the theoretical materials and that they were able to fully integrate daylighting science in their future design work, groups of students were requested to conduct a research project and present it. The experiment was conducted in two phases, the first dealt with the evaluation of the daylighting performance of an existing space, and the second investigated possible enhancements using various daylighting systems.

2.2.1 Evaluation

In the first phase, each group of students chose an existing space on the university campus. The space was modeled using the simulation software Ecotect and exported onto Radiance for analysis of daylighting performance. Illuminance values and distribution with space rendering were examined by comparing existing values with recommended standards according to the function of the space and furniture distribution (Figure 2).



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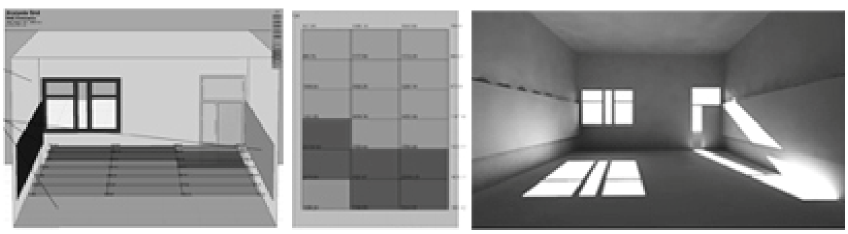

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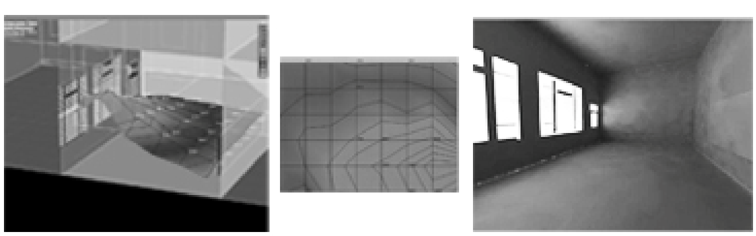
Figure 2. Sample of student's work in the evaluation stage of the research project

2.2.2 Enhancement

The second phase concentrated on utilizing the software to experiment with means of improving daylighting performance. Students explored solutions dealing with the design of existing windows, developing designs of light shelves to deliver natural light into depth of spaces and suitable shading devices to prevent unwanted direct solar penetration for the existing space. In all cases, the software output was analyzed and recommendations were drawn (Figure 3).



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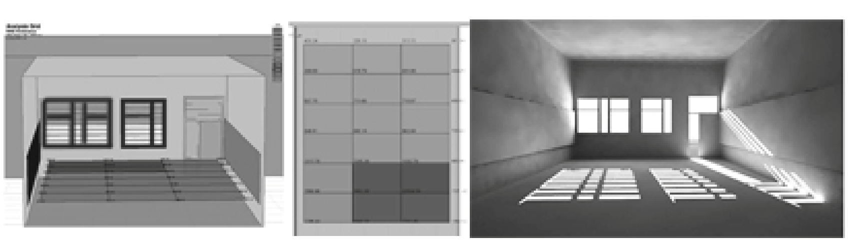

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Figure 3. Sample of student's work in the enhancement stage of the research project

3 Assessment method of software integration

An initial survey was conducted to the eighteen students attending the course in the Fall 2009 semester, before introduction of simulation software. The aim was to gauge their attitude towards CAD, preferred learning styles and understanding of daylighting. After they had been exposed to the simulation software, an in-depth interview was conducted with a sample of students. The results of this interview gave insight into potential questions to be included in the post-survey (Figure 4). The survey findings were then tabulated and analyzed.

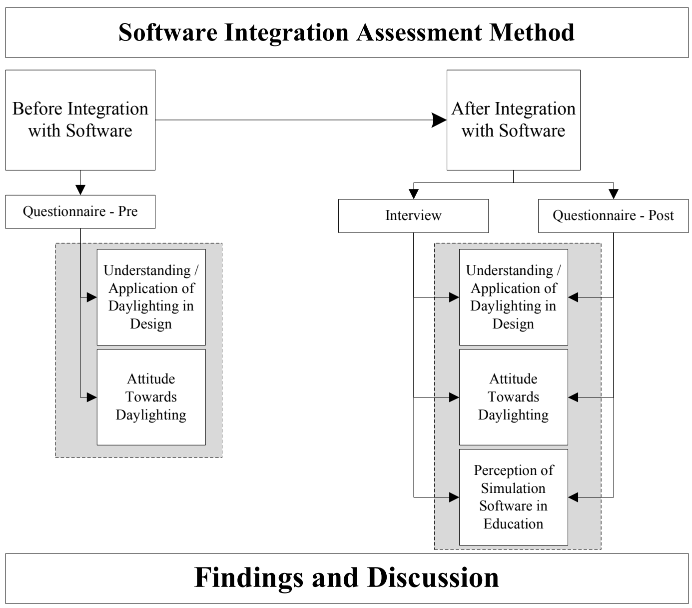


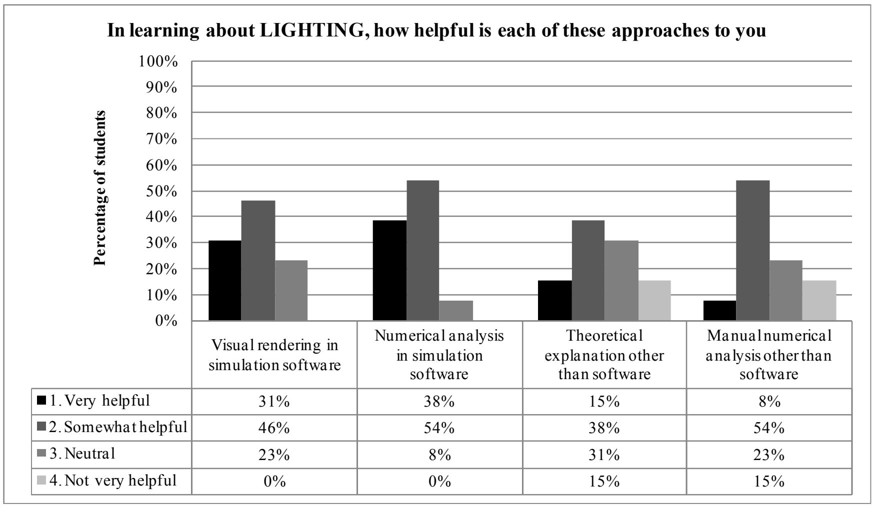
Figure 4. Software integration assessment methodology

4 Research findings

Findings from pre / post surveys and interviews were grouped into three categories. Each category dealt with student's responses in terms of perceptions towards integration of the simulation software in their education, its affect on their understanding / application of daylighting and finally their attitude towards daylighting as a science that is sustainable in nature.

4.1 Student perception of simulation software usefulness in education

The majority of the students had a positive perception of the use of software. In the post-survey, 70% found it "powerful" and "very usefull". This was not surprising since pre-survey showed that the majority of students had a positive attitude towards CAL in general. However, 85% of the students found the software: "*User-friendly when tutorials were available*". This explained that the education of the simulation software generaly requires assistance. In the in-depth interview, one student stated: *"I don't think it is very user friendly. It's easy to use but when you get into too much detail it's not user friendly"*. Nevertheless, students' overall perception of the software helpfulness to their learning is more positive than other methods of learning about lighting (Figure 5). No student thought that the software was "not very helpful", and the majority of students thought that the software was "very helpful" or "somewhat helpful" in the capabilities of visual rendering (77%) and numerical analysis (93%), as opposed to theoretical explanation (54%) and manual numerical analysis (62%).



	Visual rendering in simulation software	Numerical analysis in simulation software	Theoretical explanation other than software	Manual numerical analysis other than software
1. Very helpful	31%	38%	15%	8%
2. Somewhat helpful	46%	54%	38%	54%
3. Neutral	23%	8%	31%	23%
4. Not very helpful	0%	0%	15%	15%

Figure 5. Students' opinion on the usefulness of various methods of teaching.

4.2 Student understanding / application of daylighting in design

A number of questions in the survey were designed to test students' understanding of how to use simulation software in the design process. In terms of using them as tools for getting an accurate understanding of daylighting analysis, 60% of students showed their intention to use simulation software more often and before manual calculations. The majority also showed their understanding of when to use the software rendering capabilities according to the required task, whether it was as a quick method of analyzing available natural light (45%), or when showing a client daylighting performance in their designs (84%) (Figure 6). However, there is a confusion of when to use the software to enhance daylighting performance in a space, as more than 60% chose the rendering option rather than numerical analysis, which should not have been the case, as priority should go to numerical analysis first to give more accurate results and then visual rendering to picture the performance quality. This was probably due to an ambiguity of posing the question. But when students were asked to prioritize their choices of daylighting analysis methods for designing new day lit spaces, more than 60% chose software numerical analysis as a tool (Figure 7).

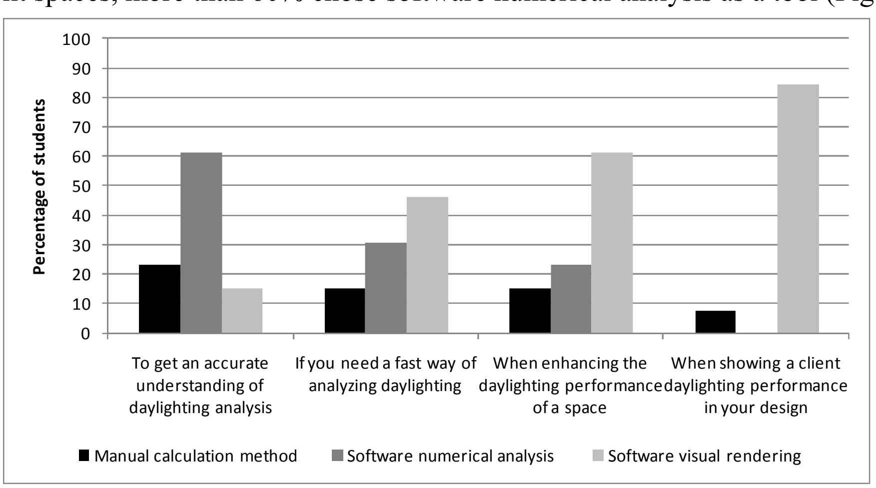


Figure 6. Use of simulation software in the design process.

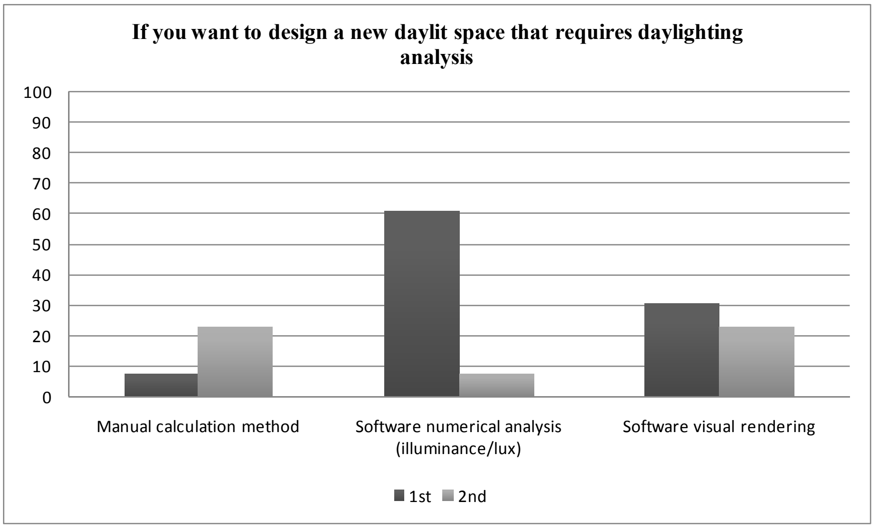


Figure 7. Student's priorities in tools of choice for designing new day lit spaces.

Two technical daylighting questions were asked in the pre / post surveys. Student responses showed that the utilization of the software as education tools was successful in delivering the importance of numerical analysis of illuminance at a point / reference plane. After engagement with the software, the percentage of students who perceived the importance of this kind of analysis rose from 85% to 100%. However, engagement with the software did not aid in clearing up scientific relationships in theory and practicality. The students' response to the relationship between theories and numerical illuminance values changed slightly from 47% to 53%.

4.3 Student attitude towards daylighting

Student general attitude towards daylighting was not considerably changed due to the use of simulation software. They were quite positive about daylighting and its importance as a building science even before serious engagement with the software (Figure 8). One student stated *"It doesn't make you feel that lighting is more or less important, it makes you realise the actual lighting that is going to be there and when you realise you can act upon it"*.

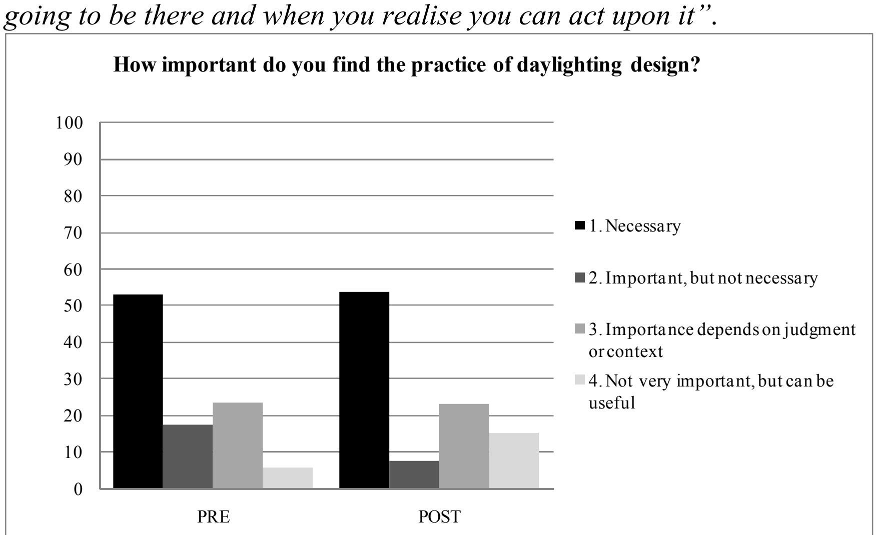


Figure 8. Students' view on the importance of daylighting in pre / post software integration.

5 Discussion and conclusion

This paper summarized the output of an academic experiment, where simulation software were successfully integrated in the lighting module of an undergraduate building sciences course. Use of the software allowed students to quickly experiment with design alternatives, thus identifying the consequences of design decisions on daylighting performance. Students had a positive perception of the impact of the simulation software on their learning, and demonstrated they understood when/how to use it at various phases of their design. However, some concepts seemingly remain unclear to students. Interviews showed that they were not aware of how to use the software for more complex designs unless assisted. This could be due to the fact that their assignments at this early stage of education were very much straight-forward, concentrating on the basics of daylighting.

As a conclusion, integration of daylighting simulation software in the educational process of future architects facilitated their understanding of daylighting science and how to apply various systems and techniques to reach optimal lighting solutions. Through systematic trials, students were able to choose suitable daylighting schemes for different luminous settings. Output of this experiment showed that teaching daylighting science was significantly improved by the visual engagement that was offered by the computer software. Integration of these tools in the education of architects could lead to building a new generation that could effectively utilize daylighting strategies into their architectural design projects. Further research efforts should be directed towards the development of teaching methods which further utilize simulation software to explain the importance of environmental control and design. The usefulness of other building performance software should also be examined. Examples include, wind flow, thermal and acoustic performance. These should prove useful in enriching students' academic experience through testing and developing their designs.

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