The Utilization of Environmental Simulation Tools in Architectural Design Education

H Samir1, *, J K Sammakieh1 and R M Abed1

1College of Architecture and Design, Effat University, Jeddah 21478, Saudi Arabia
*Corresponding author. Tel: +966 545031959, e-mail: hahussein@effatuniversity.edu.sa

Abstract. In architecture pedagogy, the architectural design process is a creative one. It relies on the ingenuity of the student to use all key issues of a building problem and interpret them as spatial elements, which are incorporated within the building design. The emphasis on the environmental design of buildings is a significant step due to the increasing awareness of the use of passive systems and strategies. Thus, students face increased pressure to design buildings with solutions toward environment. This paper presents a descriptive study that investigates the utilization of simulation tools in the design process to enhance the learning outcomes and allow students to become sensitive contributors to the strong link between environment and architecture. The study focuses on the tools deployed by students from studio-VIII, in the college of architecture and design at Effat University, to embed passive performance techniques during design problem solving. The paper identifies the tools students used, and the impact of using them on selective projects. Moreover, the paper applies a questionnaire among the targeted students to investigate how simulation could inform their design through different stages of the design process starting from the pre-design studies to the final feedback on their design. The findings illustrate how simulation tools were used integrative to building design. The selected projects identified some of the challenges faced by students to incorporate simulation methodologies during a routine design studio process and advocate considering the design problem-solving patterns and preferences in the improvement of environmental design.

Keywords. Building performance, Environmental simulation, Design studio, Architecture education

1. Literature Review

1.1. Introduction

The building sector is currently facing an increasing challenge to environmental and energy concerns. In this regard, there was an immediate need to devise technologies that would enhance the development of ecosystem friendly and energy efficient structures. The application of the Environmental simulation tool (EST) as one of these technologies has proven to be crucial in designing and modeling environmental and energy compliance buildings [1]. Therefore, applying the environmental simulation tools had become a growing interest among students and instructors in the architecture education. Consequently, the study focuses on the tools deployed by students from Studio-VIII, in the College of Architecture and Design at Effat University, to embed passive performance techniques during design problem solving. The paper points to the significant potential of applying environmental simulation tool (EST) within the design process to inform a sustainable design.

1.2. The implications of emerging developments in the design practice on architecture design pedagogy

A number of contemporary approaches and trends in the design practice now have left its implications on architectural design pedagogy. The tendency toward green design and environmentally sustainable approaches has been given much attention within the profession. Both architects and property owners are currently seeking to pursue green building certification. Numerous green building certification
programs are available now to ensure the application of sustainability measures in buildings; the most popular certification program is the LEED (Leadership in Energy and Environmental Design) which is administered by Canada and US Green Building Councils. The teaching and practice of sustainability have become a necessity in the field of architectural design [2]. This entails addressing the issue of sustainability for students not only through theoretical courses but also in their practical design studios. Thus, to better address the demand for sustainability, an integrated design approach emerged with the aim of creating high-performance buildings, which can minimize environmental impact and reduce non-renewable energy demands. The integrated design approach is defined as a process in which building design seeks to achieve high performance on a wide range of well-defined environmental and social goals while maintaining budgetary and scheduling constraints [3]. It relies upon a multidisciplinary and collaborative team whose members make decisions together based on a shared vision and a comprehensive understanding of the project. It follows the design through the entire project life, from pre-design through occupancy and into operation. The Integrated-Building Design approach varies from the conventional design method. It embraces various physical aspects of building performance, such as sitting and orientation, building form and structure, the mechanical system, material and furnishing selections, lighting, along with other building systems and components as a whole in the design process. Architects should no longer think only in functional space planning. Instead, they are important co-players in the Integrated-Building Design process. Their responsibilities within the design team should include adjusting space planning according to HVAC zones, mechanical rooms, equipment, ductwork and piping, fire egress, lighting, and window operation and façade treatment relative to energy efficiency; and coordinating interior components to passive solar energy and other sustainable approaches.

Another important factor, which affects the design practice, is the recent advancements in digital technologies and computation tools, which have been consistently changing the design process. These recent developments and emerging tools in design practice pose new demands on educators to re-investigate the significance of digital tools in architectural design curriculum. Building performance simulation, in particular, has offered students an opportunity and challenge in their sustainable design practice.

A collaborative approach to the delivery of an environment-related design must be considered, this presents an intrinsic departure from existing curricular structures [4]. Yet, if the development of an educational methodology for the enhancement of sustainable environmental design in university curricula proves successful, graduates could remarkably contribute in improving the energy performance of buildings and, ultimately, contributing to meeting global challenges within a creative design process.

1.3. Decision Making in Design Studios
In architecture education, the design studio is regarded as the backbone of teaching and learning; most schools of architecture allocate 30% to 50% of their curriculum to design practice [5]. As a learning environment, the studio is the physical platform for learning and teaching; students actively interact with each other and with faculty. The studio is where the enculturation of students into the profession takes place, and where students acquire knowledge and skills that influence the way they perceive the built environment [6].

Conventional teaching practices in design studios typically impose importance on formal aesthetics. Students are guided to be convinced that the primary goal of studio learning is to design highly creative and extraordinary forms. Many instructors embrace this aesthetic approach as the norm for teaching design studios, placing emphasis on the artistic endeavor of architecture. Other more practical instructors stress on the importance of the functionality of space planning as the main concern of the design. Some approaches claim that the design processes should start with a design concept, regardless to what extent the proposed concept serves the project needs and solves the practical spatial problems. Most of the students following this approach perceive design as cryptic analogies or metaphors. In another perspective, design is viewed as a technological entity. In this pedagogical approach, students are taught that design is driven primarily by technological forces and that the main purpose of studio education is to gain expertise in design technology [7].
These views disregard the role of design as a social responsibility where decision-making has to embrace different viewpoints and a diverse set of factors that must exist concurrently to achieve a comprehensive studio experience and fulfill the need for a broader and all-inclusive design studio education. In design education, the design studio should consider a range of contextual sets. It is an artist’s studio where creativity and aesthetics are explored, a lab where experiments in building performance are conducted, it is a venue where philosophical thoughts and design theories are examined, and it is a social workshop where the relevance of socio-cultural aspects of a design are addressed [7].

1.4. Environmental Simulation Tools
Recently, the application of the EST has proven to be crucial in designing and modeling environmental and energy compliant buildings [1]. The implementation and sustainability of these computational systems have not only changed the model of structures but also the concept of architectural practices. EST is typically used to generate prototypes that help with decision-making by processing available data to create design solutions [8]. Currently, there are two types of environmental simulation tools (EST): digital and laboratory. Digital EST consists of construction analysis and designs systems that concentrate on the conceptual outline of structures [1]. It incorporates inbuilt features such as solar radiation and energy evaluation capabilities, which create, evaluate and refine the model of the entire plan. Some of the typically used digital EST are: Revit Vasari, insight 360, and Ecotect. Laboratory EST, on the other hand, is a construction technique where the project is developed through complex estimation and calculation using a defined formula or framework [9]. It is significant in establishing the actual dimensions of a structure that adheres to the effective energy consumption, sustainability, and other building codes. Some of the available laboratory models include Artificial Sky equipment and Heliodon amongst others.

2. Method
The study was carried out on two design projects from the architectural design studio-VIII course (ARCH-408) through the two consecutive semesters of fall 2018 and spring 2019. 84 students were enrolled in the fall and were subdivided into five classes, and 93 enrolled in the spring and were subdivided into seven classes. Both batches applied the same integrated (comprehensive) approach, and both were required to employ sustainability principles in their design development as a component of the approach, especially in the form generation, massing, orientation and façade treatments. They also attended a lecture conducted by an instructor who had working knowledge in computer simulation tools and green building rating systems on how to investigate their buildings’ environmental performance. The total duration of the project was fifteen weeks. A jury of two evaluators were invited to judge the students’ final presentations at the end of the two semesters. All jury members had teaching and/or practical experience in architecture.

The study investigates the integration of environmental building performance in the design process as a component of comprehensive design in one selected project from each semester. The reason for selecting these two semesters was the fact that a new studio delivery approach had been applied based on the recommendation of the (NAAB) US National Architecture Accrediting Board during their second visit to the program for substantial accreditation equivalency. It differs from the old delivery mode in five key aspects: the establishment of new comprehensive design knowledge, the required deliverables such as the analysis done by digital and laboratory performance simulation tools, the way of organizing classes as the project was carried out by a group of two or three students instead of an individual student, and the size, which was smaller and had a less complex project program as compared to the previous semesters. This was critical to the success of the process and the idea that there must be sufficient time for the students to acquire knowledge for the needs of each building system and to explore the impact of that knowledge while they refine the overall design in an iterative process of integration.

Students of the fall semester were asked to design a car show room for one of the recognized car-brands. On the other hand, students of the spring were given a project of a research center. The given site of the two projects is located in Jeddah, Saudi Arabia. Design problems included building form
generation, space planning, landscape design, as well as correspondence to the surrounding context, climate, solar orientation, prevailing winds, and views. Students were encouraged to employ performance simulation tools to guide their design and form generation decisions.

The intention of the two projects was to deliver new designs based on expanding the knowledge of the students beyond the mere functional design skills to better understand the comprehensive approach. Attention was given to five key areas: the structure, environmental considerations, envelope design and fenestration, electrical and mechanical space planning and fire safety. This research was only concerned with how environmental considerations were applied in the comprehensive design process through two aspects: Integrating passive strategies as one of the sustainable design principles, and integrating Building Performance tools to enhance understanding of the interrelation between internal spaces and external conditions.

2.1. Instruments
To investigate the effectiveness of building performance simulation tools on students’ work and their design decisions, data was collected from two selected projects, on which various digital and laboratory tools were applied to guide design decisions. One project was from fall 2018 and the other was from spring 2019. The data was collected through two methods: observation and questionnaires filled out by students after their final presentation. The data collected from observation was concerned with the types of environmental simulation tools used and how they guided the design during different phases of the design process, in terms of their impact on the created and developed architectural elements, which involved the use of efficient passive and active design systems. The questionnaire included multiple-choice questions, asking students to evaluate both digital and laboratory simulation tools and indicate their preferences regarding them. In addition, open-ended questions were included to inquire about in which stage these tools were applied, as well as to take note of patterns among the students’ learning experience. The observation and questionnaire were the instruments that served the basis for this study’s interpretation, conclusions and suggested directions for future teaching practice.

3. Case Studies
3.1. Architectural Design Project of fall 2018 – Jeep Automotive Showroom
3.1.1. Project Brief. The students’ mission from the comprehensive design studio-VIII of fall 2018 was to design a showroom in the city of Jeddah that represents and reflects the identity of a car company of their choice. This project closely considered the fundamentals of human thermal comfort through considering a climate-responsive building design. Hence, to achieve an efficient climatic-responsive design, digital EST were used. This had a significant impact on how the project was designed. The design of the project responded to the outcomes of the EST analysis, which in consequently, made the building achieve its most suitable climatic-responsive design option. In addition, the design responses were extracted through the following digital programs: Autodesk Revit for the shading analysis, Autodesk Insight 360 for the solar analysis, and Weather Tool for the macro-climatic analysis and determining passive design strategies.

![Figure 1](image1.png)  
**Figure 1:** Façade treatment of the showroom extracted from Autodesk Revit (Design Studio-VIII of fall 2018).

![Figure 2](image2.png)  
**Figure 2:** Shading analysis in December and June 21st extracted from Autodesk Revit (Design Studio-VIII of fall 2018).
3.1.2. Autodesk Revit: Shading Analysis. The Revit Shading Analysis was an essential tool used in the latest stages of the design process to examine the efficiency of the design. It gave confirmations on the design in terms of its orientation, form, placement of openings, and the façade treatment (Figure 1). The analysis on the building was made at 9:00 am, 12:00 pm and 3:00 pm in two different months: June and December, which represents summer and winter. In summer, the sun was at its highest altitude (83.87) on 12:00 pm with an azimuth of 70.29º. While in winter, the sun was at its highest altitude (44.80) on 12:00 pm with an azimuth of 173.10º (Figure 2).

3.1.3. Autodesk Insight 360: Solar Analysis (Plug-in to Autodesk Revit). Insight 360, which is a plugin program to Autodesk Revit, was used throughout the design development stages of the project to analyze how much of the sun’s solar energy would hit the building. Moreover, it contributed to designing the mass of the project. Besides, using this Solar Analysis tool helped form an overall idea of which elevation was gaining more solar radiation and which was gaining the least. Thus, it helped to place the shading devices on the most suitable facades. The outcomes of the Solar Analysis also affected the choice of materials and location of openings (Figure 3).

![Figure 3: Solar Analysis in December and July 21st extracted from Autodesk Insight 360 (Design Studio-VIII of fall 2018).](image)

3.1.4. Weather Tool. Weather Tool is a program that can be used to give accurate data of the climatic conditions of any selected city. Thus, it was used as the main program in the pre-design phase of the project. It was able to provide accurate data of Jeddah’s Marco Climatic conditions in the form of charts (Figure 4). The following data was concluded: the prevailing winds of Jeddah are from the north, the average relative humidity is 65%, and the average wind temperature is 30ºc.

![Figure 4: Macro-Climatic analysis of Jeddah, Saudi Arabia (Weather Tool).](image)

In addition, Weather Tool indicated through a Psychometric Chart for the given location many passive design strategies that can be used to optimize energy efficiency and occupant comfort. According to Weather Tool, the most suitable passive technique for Jeddah’s climatic conditions is natural ventilation; none of the other strategies were valid to be used in a city with Jeddah’s conditions (Figure 5). However, the Natural Ventilation technique was not reflected in the project design as it...
does not suit the project’s type and occupancy, which is Mercantile and Business types of occupancy.
In addition, the Psychometric Chart suggested supporting the project with an Air Conditioning system that is placed to control temperature and provide better air quality (Figure 6).

![Figure 5: Psychometric Chart of Jeddah, Saudi Arabia (Weather Tool).](image)

![Figure 6: The Automotive Showroom AC Packaged Units extracted from Autodesk Revit (Design Studio-VIII of fall 2018).](image)

3.1.5. Results from the project. The use of Environmental Simulation Tools EST helped shape the final design of the project through giving suggestions, guidance, and providing tests in the following aspects: building orientation, massing, placement of openings, materials and façade treatments.

Studying the climatic conditions in the pre-design phase contributed to directing the project towards the northern orientation to take advantage of the prevailing wind (Figure 7). This provided the showroom with an adequate amount of natural light avoiding direct exposure to sunlight. Also, it allowed its glazed openings to be wide and not heavily covered with shading devices. Hence, highlighted its importance and strengthen its presence from the outside to the customers. While studying the Solar Radiation have assisted in designing the building mass. Consequently, the mass was designed in different sizes and heights to minimize the need for using shading devised and maximize the benefit of the self-shading techniques. Moreover, it contributed to the choice of façade treatment. Therefore, an aluminum cladding has been applied as a treatment to the building facade. Furthermore, the study of shading was used in the latest stages to examine the efficiency of the whole design decisions. Thus, the outcomes of analyzing the accuracy of shading were able to give confirmations on the design in terms of the orientation, form, placement of openings, and the façade treatment. Accordingly, this led the project successfully to its final design stages.

![Figure 7: Orienting the Automotive Showroom to the north extracted from Autodesk Revit (Design Studio-VIII of fall 2018).](image)

3.2. Architectural Design Project of spring 2019 – Heritage Research center
3.2.1. Project Brief. The proposed project of spring 2019 was a research center dedicated to the study of the natural heritage of Saudi Arabia (Figure 8). The application of digital and laboratory environmental simulation tools (EST) in the early stages of the design led to the best climatic-responses and design decisions. In addition, the environmental simulation tools EST were used in
parallel with the design process and they were: Autodesk Revit: Shading Analysis Tool, Revit Vasari Tool, Autodesk Insight 360: Solar Analysis, Helidone Laboratory Tool.

![Figure 8: Heritage Research Center main entrance extracted from Autodesk 3ds Max (Design Studio VIII Project of spring 2019).](image)

**Figure 8:** Heritage Research Center main entrance extracted from Autodesk 3ds Max (Design Studio VIII Project of spring 2019).

3.2.2. **Autodesk Revit: Shading Analysis.** The design development of the building form applied Autodesk Revit: shading analysis feature that helped to produce single images to show the casted shadows. Consequently, manipulating the masses were extremely influenced by testing the shades and shadows (Figure 9).

![Figure 9: Design development extracted from Autodesk Revit (Design Studio VIII Project of spring 2019).](image)

**Figure 9:** Design development extracted from Autodesk Revit (Design Studio VIII Project of spring 2019).

The design development started with the concept of having two main masses representing the two features of nature, the seaside and the landside. Then, adding a courtyard to create an inner view and provide vegetation. Afterward, lowering the north-western side of the building to catch the prevailing wind and increase the height of the building from the opposite side to allow the courtyard as well as some parts of the building to be shaded. Finally, using the shell structure in the main building public spine to provide natural daylight from the clerestories created between the shell segments.

3.2.3. **Autodesk Revit Vasari Tool.** Autodesk Revit Vasari features an interactive 3D sun path diagram, which helps in visualizing shadows and understanding the sun’s position throughout the day and year. The first stage in the design process was visualizing the casted shadows on the site with its surrounding throughout the year. This contributed in reaching a better understanding of the site and its adjacent surroundings (Figure 10). Afterward, the building masses were analyzed in two different months: June and December, which represents summer and winter. In addition, at three times of the day: 9:00 am, 12:00 pm and 4:00 pm. In summer, the sun was at its highest altitude (83.9°) on 12:00 pm with an azimuth of (70.5°). On the other hand, in winter, the sun was at its highest altitude (45.3°) on 12:00 pm with an azimuth of (174.5°) (Figure 11).

![Figure 10:](image)
3.2.4. **Autodesk Insight 360: Solar Analysis.** The solar analysis feature allows visualizing and quantifying the distribution and intensity of solar radiation on various areas on a mass, taking into consideration the shading effects from adjacent objects. The investigation of the distribution and intensity of the solar radiation hitting the building envelope indicated that it is minimized by the masses’ heights and composition as shown with the blue range of colors, such as in the courtyard (Figure 12).

3.2.5. **Helidon Laboratory Tool.** The helidon laboratory building simulation and investigation tool simulate shade, shadows, sun penetration and solar access on a physical scale model. The device simulates the relationship between the sun and the building. The three variables that affect this relationship are latitude, time of the year and time of the day. The helidon has a light source, an artificial ground plane, and three adjustments so that the light strikes the ground plane at a proper angle corresponding to the latitude, time of the year and time of the day desired [10]. The building masses were investigated in the helidon laboratory tool in the mid-stage to the final stage of the design process through a mass model. It was investigated in two different months: June and December which represents summer with a green light color and winter with blue light color. It was investigated in three times of the day: 9:00 am, 3:00 pm and 4:00 pm (Figure 13). The experiment verified the same outcomes from the previous studies using digital environmental simulation tools, Such as the shaded courtyard and the backside of the building.

3.2.6. **Results from the project.** The final design shaped many elements and aspects resulted from studying and investigating the building performance throughout both digital and laboratory...
environmental simulation tools. These aspects are the massing, building orientation, adequate natural light, heat gain reduction, cooling the building envelope and directing the prevailing wind to the open spaces.

The designed massing and building orientation are provided shading to the courtyard as well as the backside of the building, allowing the prevailing wind to cool down the envelope temperature. This was achieved by allowing the glazed area to be oriented to the north direction. Therefore, the interior spaces were provided with an adequate amount of natural light avoiding direct exposure to sunlight (Figure 14). The central part of the building is a courtyard provided with seating areas and vegetation, and due to its significance, the massing configuration considered shading (Figure 15). Thus, it decreases the heat gain imposed on the courtyard giving a better thermal performance.

![Figure 14](image1.png)  
**Figure 14:** Triple height stepped space provided with adequate natural light extracted from Autodesk 3ds Max (Design Studio VIII Project of spring 2019).

![Figure 15](image2.png)  
**Figure 15:** Inner shaded courtyard showing seating area and vegetation extracted from Autodesk 3ds Max (Design Studio VIII Project of spring 2019).

The study of the solar radiation and its intensity on building facades contributed to the choice of the building claddings and treatments. Therefore, the facades implemented three different treatments: Glazed curtain wall, GRC cladding, and exterior paint (Figure 16). The solar analysis shows that the courtyard is shaded most of the day. Thus, the spider-supported curtain wall is used in the facades directed to the courtyard. Besides, the solar analysis informs that the highest solar radiation hits the western and eastern elevations. Hence, a thermal insulated GRC treatment was applied to these facades.

![Figure 16](image3.png)  
**Figure 16:** Bird’s eye shot showing building masses, claddings, and treatments extracted from Autodesk 3ds Max (Design Studio VIII Project of spring 2019).

4. The questionnaire
An online questionnaire was conducted and a total of 50 responses were collected. The analysis was made on the comprehensive architecture design studio-VIII students of Effat University. The number of students answered this questionnaire of whom took the comprehensive studio of fall 2018 were...
56% while 44% were from spring 2019 semester. It was noted that 82% used Autodesk Revit to generate their masses, while the remaining 8% selected other programs, which is considered low compared to those who used Autodesk Revit (Figure 17).

![Figure 17: Modeling program preferences.](image1)

When asked why they used this specific program, 82% answered that it is because they are more familiar with it and have better skills with its tools. 12% preferred the program as it is easier than others. Moreover, only 2% preferred it as it was recommended by their instructor, 2% for its effectiveness in presenting conceptual forms, and 2% preferred using the different program in each stage. The majority of students 84% applied digital EST on their projects, compared to 16% did not apply. Moreover, when asked about what digital EST used; 66.7% said they used Autodesk shading analysis, 59.5% used Weather Tool and 52.4% Ecotect. The remaining answers varied between Climate Consultant, Autodesk Insight 360, Autodesk Revit Vasari, and Autodesk Flow Design (Figure 18).

![Figure 18: Digital environmental simulation tools used by students.](image2)

In regard to laboratory environmental simulation tools, 82% mentioned that they did not use any laboratory tool to inform the design decisions, while the remaining 18% said they applied laboratory EST in their comprehensive studio. Moreover, 50% have used the artificial sky laboratory Tool, while the remaining 40% used the helidone laboratory tool. When asked about the phases in which using these tools helped them better; 48% found them helpful when used in the pre-design phase, while it was more helpful in the design development phase for 34%, and in the schematic design phase for only 10% of participants. Only 8% used EST in the design assessment and validation.

There was a clear variation between participants’ choice of how EST assisted them and affected their project positively. 73.5% used EST indicated that it helped them orient their building towards the most efficient direction, other 73.5% benefited in designing the shading devices. While it helped 65.3% in designing spaces with natural light. The remaining answers varied between massing, heat gain reduction, natural ventilation, and fenestration design (Figure 19).
Figure 19: The impact of using EST in adopting passive design strategies.

Participants were also asked whether the EST both the digital and laboratory have a significant impact on building the final design project, to which 74% answered yes and 26% answered no. Furthermore, the 50 students who participated in this questionnaire were asked to name the courses in which they applied environmental simulation tools. The majority of participants used the EST in their energy and design course (Figure 20), while the remaining participants’ answers varied between using the EST in their capstone project, capstone project preparation, housing, and economics, or they did not use it except in the comprehensive design studio-VIII.

Figure 20: Architecture courses in which environmental simulation tools were used.

5. Results and Discussion from the questionnaire

It was initially expected that EST both the digital and laboratory have a significant impact on the comprehensive design studio-VIII projects of Effat University students. This was proved through this study, which was conducted using an online questionnaire. This study found that most of the students concurred with that using EST played a remarkable role in impacting their design outcomes, as it contributed in massing, building orientation, heat gain reduction, natural ventilation, natural light, shading devices design, openings, and fenestration design.

When asked about the digital EST, most of the responses indicated that students used Autodesk Revit to generate their masses, and it was because they had better skills with its tools and as well as because they are offered Autodesk Revit course in their curriculum, which at the end, leads them to find it easier and familiar to use. Moreover, Autodesk Revit in comparison with other digital programs is supported with many EST and plug-ins such as shading analysis tool, vasari tool, insight 360, and flow design amongst others. Furthermore, the mentioned EST were used by a high percentage of students.

Many of the participants did not use laboratory EST. This could be due to its difficulty as it requires physical models to do the experiments. Moreover, those who used laboratory EST preferred artificial sky laboratory Tool slightly more than the heliodone laboratory Tool. Furthermore, most of the participants preferred using the EST both the digital and laboratory in the pre-design phase, and in the design development phase of the project. However, fewer participants preferred using EST in the schematic design as well as in the design validation phase. The reason behind this is that participants found using EST in the early stages of the project contributes to taking effective design decisions that
when efficiently implemented; leads to better building performance. On the other hand, participants favored using the digital EST more than the laboratory EST as they found it less time consuming and easier to be applied and integrated during the design process.

After taking the comprehensive design Studio-VIII, students rated the experience of using environmental simulation Tools for the first time in a studio project as positive. Hence, they were encouraged to use it in plenty of other Architecture and Design courses. Not only but also, many students are showing a willingness to apply EST in their graduation projects with indicating that it helped speed up the design phase and produce a good workable final design.

6. Concluding Remarks
This study, successfully, responded to the challenges imposed by the demanding needs of sustainable and green buildings, and the fact that marketplace nowadays require architectural graduates capable of incorporating a variety of integrated problems which include, other than skills in creative problem-solving design, also the competence of environmental concerns. For this to take place, a comprehensive approach of the design studio offered by architecture education curriculums is needed, so as to ensure that the promotion of sustainable environmental design is a central notion of the curriculum towards the professional practice of architecture.

The study indicated that there exist a variety of digital and laboratory tools for building an environmental simulation, analysis, and assessment of performance aspects. It asserted that concern toward incorporating these tools in design studio presented in this paper revealed a considerable shift in the way students can better compose meaningful designs, which are corresponding to the needs of improving the energy performance of buildings within a generative design process with performance. The results indicated the overall success of the EST. It was evident that Digital simulation of building performance impacted the design process and improved students’ design outcomes.

The results also affirmed that EST was effective in providing early awareness of the environmental conditions for students in the pre-design and site analysis phase. It also enhanced students’ understanding of the interrelationship between external factors and the internal designed spaces during the design development phase. The study concluded that EST affected the students’ design decisions in different ways. Particularly, with building orientation, shading devices design, effective natural light, massing, heat gain reduction, natural ventilation, and fenestration treatments.

References
[1] Bouchlaghem D, Shang H, Whyte J, and Ganah A 2005 Visualization in architecture engineering and construction (AEC) Automation in construction vol 14(3), pp 287-295
[2] Zuo Q, Leonard W, MaloneBeach EE 2010 Integrating performance-based design in beginning interior design education: an interactive dialog between the built environment and its context Design Studies vol 31(3) pp 268-287
[3] Busby Perkins, Will and Stantec Consulting 2007 Roadmap for the Integrated Design Process developed for BC Green Building Roundtable
[4] Altomonte S. 2009 Environmental education for sustainable architecture. Review of European Studies vol 1(2): p 12
[5] Salama A M 2005 A process-oriented design pedagogy: KFUPM sophomore studio CEBE Transactions, vol 2 (2) Sept pp 16-31
[6] Tumusiime, H 2013 Learning in architecture: Students’ perceptions of the architecture studio. Proc. Int. AAE Conf. on architecture education (Nottingham)
[7] Fernando N 2007 Decision Making in Design Studios: Old Dilemmas-New Strategies Design studio pedagogy: Horizons for the future (Electronic Materials) ed A M Salama and N Winkilson (Gateshead: The Urban International Press) chapter 2 pp 143-152
[8] Woloszyn M, & Rode C 2008 Tools for performance simulation of heat, air, and moisture conditions of whole buildings. Building Simulation vol. 1(1) pp. 5-24
[9] Machairas V Tsangrassoulis A and Axarli K 2014 Algorithms for optimization of building design: A review. Renewable and Sustainable Energy Reviews vol. 31 pp 101-112
Acknowledgments
This paper presents the work of students at the College of Architecture and Design at Effat University. The two projects presented in this paper were carried out by two groups of students: Joud Sammakieh and Ahad Ibrahim, Refan Abed and Sara Alhassani. They are highly acknowledged for their intellectual curiosity, enthusiasm, and contribution to the content provided in this paper.

[10] Lechner N (2014) Heating, cooling, lighting: Sustainable design methods for architects
(John wiley& sons)