PORT SAID ENGINEERING RESEARCH JOURNAL
Faculty of Engineering - Port Said University
Volume 27 No. 4 pp: …

Integration of Digital Design Techniques in Architectural Education: A Case Study of the Hybrid Sciagraphy Course in Egyptian Universities

Ahmed Mohamed Saleh [1,], Muhammad Hegazy Ali[2]*

[1]Department of Architecture, Faculty of Engineering, Suez Canal University, Ismailia, Egypt, email: ahmed.khader@eng.suez.edu.eg
[2]Department of Architecture, Faculty of Engineering, Suez Canal University, Ismailia, Egypt, email: muhammadhegazy@eng.suez.edu.eg
*Corresponding Author, DOI: 10.21608/PSERJ.2023.230946.1258

Received 25 Sept. 2023,
Revised xx xxxx 2023,
Accepted 25 Sept. 2023

ABSTRACT

Sciagraphy courses remain crucial for nurturing the imaginative and design prowess of architecture students during their foundational studies. Nevertheless, amidst the ongoing digital revolution, it is imperative to reevaluate the course content and structure by involving seamless integration with emerging tools, rather than relying solely on manual drawing. The research gap addressed in this paper pertains to the scarcity of literature and case studies offering a framework for the innovative adaptation of sciagraphy courses to align with the new design tools emerging from the digital revolution, including digital fabrication and parametric design. This gap is particularly pronounced in the Arab region. This research is based on a case study of a hybrid sciagraphy course curriculum blending digital design with manual proficiency, successful in three Egyptian universities. The course merges handcrafted mockups, sketches, and digital tools, refining artisanal skills and technological prowess. Emphasizing sciagraphy and perspective hones students' imaginative capacities, formative skills, and shadow comprehension. It also prioritizes conveying concepts through shadows and exploring diverse design avenues. The paper thoroughly details the curriculum, workflow, and impressive student progress. A comprehensive survey to educators of the course was conducted, highlighting perceptual gaps in integrating digital tools into sciagraphy education. The research effectively reveals the symbiotic efficacy of digital tools in traditional courses, crucial for holistic skill acquisition. The study's implications resonate profoundly in Egyptian architectural education, effectively equipping students to adapt fluently to the dynamic architectural milieu. Moreover, the research underscores the enduring viability of such innovation, serving as a pivotal cornerstone of early architectural education in digital era.

Keywords: Digital Design, Digital Fabrication, Sciagraphy and Perspective, Architectural Education

1. INTRODUCTION

Architecture, an ancient discipline with roots dating back to the earliest civilizations, has continuously evolved and adapted to incorporate technological advancements into its educational practices [1]. Throughout history, architects and educators have recognized the importance of staying abreast of emerging technologies to enhance the quality of architectural education. However, in certain regions, particularly in developing countries, there exists a noticeable discrepancy in updating the content and methodologies of architectural education to fully leverage the potential of the ongoing digital revolution. Among the foundational disciplines within architectural education, sciagraphy and perspective courses hold a position of utmost significance. These disciplines have long served as pillars of architectural pedagogy, imparting students with essential skills and cultivating a profound understanding of three-dimensional space and the derivation of form through the intricate interplay of light and shadow[2]. Through the meticulous study of sciagraphy, which focuses on the representation of shadows, and perspective, which explores the depiction of spatial depth and proportion, students gain valuable insights into the creation and manipulation of architectural forms.

Nonetheless, as the rapid progress of digital technologies revolutionizes architectural rendering and form exploration, the continued relevance of these traditional disciplines is contingent upon their adaptation and enhancement. The advent of advanced computational tools, virtual reality, augmented reality, and parametric modeling techniques has expanded the possibilities for architectural design and representation. Consequently, there is an inherent need to integrate these digital advancements into the teaching of sciagraphy and perspective, aligning the curriculum with contemporary industry practices and equipping students with the skills necessary for success in the digital age. The transformative potential of digital technologies in architectural education is profound. Digital tools offer architects and students the ability to visualize designs in unprecedented detail, manipulate complex geometries with ease, simulate lighting and material effects, and explore alternative design iterations rapidly. Therefore, to fully prepare students for the multifaceted demands of the architectural profession, it is imperative to ensure that sciagraphy and perspective courses evolve alongside technological advancements. By embracing digital tools and integrating them effectively into the curriculum, architectural educators can provide students with a comprehensive skill set that encompasses both traditional and contemporary techniques.

This synergy between manual practices and digital methodologies allows for a holistic approach to architectural education, fostering the development of students' technical proficiency, design thinking abilities, and adaptability to evolving professional practices [3]. Addressing the disparity in updating architectural education in developing countries is of particular importance. By bridging the gap and embracing the digital revolution, these countries can empower their architectural students to compete on a global scale, participate in cutting-edge design projects, and contribute meaningfully to the built environment. Furthermore, the integration of digital technologies into sciagraphy and perspective courses has the potential to democratize access to architectural education, making it more accessible and inclusive for aspiring architects across diverse socioeconomic backgrounds. Failure to incorporate timely technological updates in such courses may lead to their eventual obsolescence, as students readily embrace technology and disregard them, despite their paramount significance in fostering students' imaginative and creative capacities. Hence, it becomes imperative to seamlessly integrate pedagogical methodologies with manual practices, nurturing manual dexterity while harnessing technology to create an engaging learning environment that captivates student interest.

This study presents a unique case study focusing on an innovative hybrid course curriculum that combines both digital design techniques, including CNC, 3D printing, and 3D modeling, and traditional manual techniques such as mockups and hand drawings. The primary emphasis of this hybrid curriculum centers on sciagraphy and perspective studies and has been successfully implemented in three Egyptian universities: two private institutions, namely Badr University and Ahram Canadian University, and one public university, Suez Canal University. The introduced curriculum incorporates cutting-edge digital methods for sciagraphy and perspective education, including 3D form modeling and the examination of shadows and shading. Additionally, the course encompasses exercises related to environmental design techniques, such as sunscreens, facade fenestration geometrical studies, and form finding through 3D massing.

The course's objectives revolve around enhancing students' imaginative capabilities, fostering skills in form generation, promoting a deep understanding of shadows, enabling expression through shadow, and facilitating exploration of diverse design alternatives. This paper thoroughly describes the course's structural framework, workflow, and its impact on student outcomes. In the course of this research, two surveys were conducted—one gathering opinions from regional experts regarding the current state of architectural education in relation to digital tools, and another survey targeting students enrolled in the introduced course to assess their satisfaction levels and objectively measure the course methodology's outcomes. The primary contribution of this research lies in the establishment of a comprehensive framework for the integration of digital tools into traditionally taught courses, while also validating the effectiveness of these techniques in the learning and skill acquisition process. The findings of this study carry potential benefits for advancing architectural education in Egyptian and regional universities, offering valuable insights into how digital tools can augment traditional practices and enhance the overall educational experience.

2. DIGITAL DESIGN AND ARCHITECTURAL EDUCATION: BRIDGING THE GAP

The field of architectural education has witnessed a growing recognition of the transformative potential of digital technologies, prompting researchers and educators to explore pedagogical approaches that integrate technology into design instruction. This section encompasses a collection of research studies that shed light on various aspects of digital design and its impact on architectural education. The studies highlight the challenges faced in effectively integrating technology, propose solutions to bridge the gap between design teaching and technology teaching, and emphasize the unique body of knowledge that digital design brings to architectural concepts. Furthermore, the section delves into the pivotal role of the design studio as a core component of architectural education, where students engage in hands-on learning and critical thinking. It also examines the relationship between emerging technologies and architectural theories and practices, uncovering the multifaceted roles that digital tools play in representation, simulation, evaluation, and the connection between design and construction. Together, these studies provide valuable insights into the evolving landscape of architectural education and the integration of digital design methodologies.

Bridges [4] addressed the limited research and discussion on pedagogical approaches in architectural education and the potential of Problem-Based Learning (PBL) as a solution to the challenges faced in this field. The paper conducted a critical review of PBL implementations at TU Delft in the Netherlands and Newcastle University in Australia, with a specific focus on the teaching of architectural computing. Doyle and Senske [5] focused on the relationship between digital design, architecture, and architectural education. It highlighted the transformative impact of digital technologies, such as computational design and digital fabrication, on contemporary architecture. However, it also pointed out the challenges faced by architecture schools in effectively integrating technology due to a lack of educational theory and widespread misconceptions about teaching digital skills. In response to these challenges, the authors presented two proposals. The first proposal addressed the integration of soft skills for digital design, emphasizing the importance of teaching non-technical aspects alongside technological competencies. The second proposal proposed the use of Bloom's Taxonomy as a framework for developing learning objectives in digital design instruction. Both proposals aimed to bridge the gap between design teaching and technology teaching in architectural education.

Gallaset al. [6] emphasized that digital design constitutes a unique body of knowledge and architectural concepts. The authors argued that digital design has influenced the development of theoretical, computational, and cognitive approaches in design education and pedagogy. They emphasized the importance of appropriate software packages and parametric modeling skills in simulating and controlling complex geometries, and suggested that before training these skills, it is essential to provide a historical context for digital parametric design, exploring the origins of the terminology and its use in science, arts, architecture, and structure.

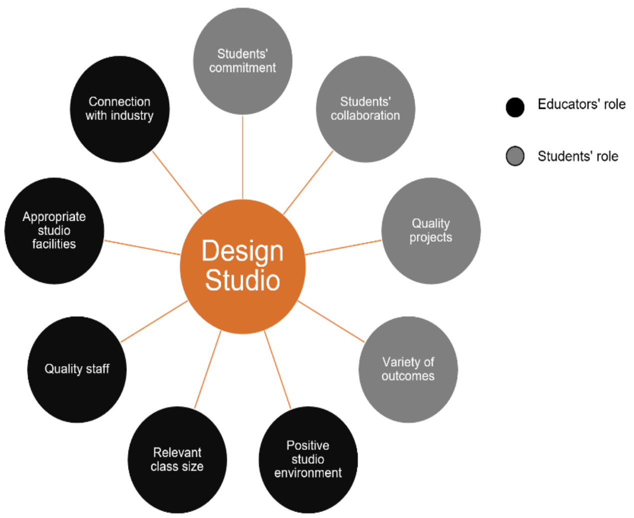

Figure 1: Factors of creating a successful design studio environment [11]

In architectural education, a design studio is a course in which students learn how to solve design related problems and build their own conceptual design workflow [7]. Since its beginning, the teaching of architecture has been mainly driven by the design studio training at schools of architecture, with critical thinking and critique have been at the core of the education process. The uniqueness of the design studio environment lies in its contrast to instructive education, where students are constrained by explicit guidance, design studios enables students to acquire knowledge and skills through learning-by-doing [8]. There, the studio is considered the main medium of architectural design education where the conversation between mentor (tutor) and mentee (student) evolves into maturity [9]. According to Zehner et al. [10], a design studio education can be deemed successful within nine factors: 1) appropriate studio facilities 2) connection with industry 3) variety of outcome projects 4) relevant class size 5) students collaboration 6) positive studio environment 7) quality staff 6) quality projects 9) students commitment [11] (Figure 1). As a technology intensive field, architecture has been adopting emerging technologies, primarily digital ones into its theories and practices from early stages. Digital technology poses five main roles in architecture; 1) as a representative tool 2) as a simulation tool 3) as an evaluation tool 4) connection between design and construction 5) connection between digital information and development [7].

3. DIGITALIZATION OF ARCHITECTURAL EDUCATION: EXPLORING IMPLEMENTATION AND PERCEPTIONS

Digital design and fabrication methods and tools have been embraced in architectural education since a while [12], and have been ever since showing increasing potential in improving the design studio frameworks and outcomes regarding several aspects. Several studies define digital design and fabrication as an approach that mainly uses digital tools (e.g. CAD software) to explore and realize design solutions [13]. As part of a wider Digital Architecture (DA) paradigm, digital design and fabrication practices in architecture have been looming towards a dominant role in both industry and academia. As a result, digital design and fabrication abstracts and technicalities influence foundational architectural education [11]. However, there is still an ongoing debate around the current perceptions and implementation of digital design and fabrication in Design courses, especially in non-western education cultures. For example, a survey by Karadağ and Tuker [14] on the state of digital design and fabrication in architectural courses in Turkish universities. It was found that computer-based design courses merely focus on digital design and fabrication tools and software as a skilling process, rather than elaborate on the more comprehensive approach of "computational thinking". In addition, most digital design and fabrication-related courses are electives, meaning they don't incorporate directly into the design studio education. There are also challenges related to the perception of architecture students on computational design. For example, McCullough [15] states that many students are reluctant towards learning computation techniques due to their perception about how computation is too difficult or out of sight of their design conceptualization process.

In this context, there have been several experiments within the pedagogical approaches that can fully utilize digital design and fabrication potential as a driver of the design studio in university architectural education. Roudavski [11] showcased one example at the University of Melbourne of such influence of digital design and fabrication on education through an example of the Virtual Environments course, a part of the Bachelor of Environments program. The study argued that digital architectural design can be utilized in education beyond the conventional stylistic or novel paradigm but as a catalyst for experimentation and creativity among students. Schroeder and Dean [16] implemented digital design and fabrication methods in the form of using node-based software in conjunction with BIM software to explore adaptive structural design solutions. Despite being implemented at the first-year coursework, the authors found that visual programming implementation was successful and indicates the effectiveness of introducing digital design and fabrication into early stages of architectural education.

In another experiment to implement computational design into the environmental aspect of architectural design studio, Karadağ and Tuker [14] organized a 10-days digital design and fabrication research workshop for architecture students, driven by the two main objectives to identify the effects of digital design and fabrication thinking and tools on environmental awareness in the design studio, and investigate whether digital design and fabrication skills can impact the designer's awareness regarding ecology in the design decision making processes. The study found that integrating digital design and fabrication thinking and tools in the design studio has noticeably improved environmental awareness among students throughout the design process. Also, the data-driven nature of digital design and fabrication enabled better integration of contexts and constraints, as well as realizing a framework for optimal design solutions at multi-criteria levels. Agirbas [17] addressed one of the challenges regarding teaching parametric design -as one sub area of digital design and fabrication- in architecture schools, embodied in the limitation of the outcome designs to the modelling stage. In her study, a Grasshopper elective course was showcased as an example of learning-by-doing method in parametric design, where students utilized parametric thinking and tools not only to design, but to fabricate a parametric bench (Figure 2).

Figure 2: Parametric bench as a fabricated output of parametric design course [17]

Regarding neighboring disciplines to architectural design, such as landscape architecture, digital design and fabrication also was investigated for its influence on the design process and outcomes. In a study by Belesky [18], digital design and fabrication tools were implemented in the "Communications 2" course at RMIT. The researchers concluded that architectural teaching that involves digital design is often a skilling exercise. It also encourages the approach towards outsourcing of learning such as online video. While it can be useful for the mechanical tasks of executing commands in the software, they fail in encouraging space interaction and collaboration and thus doesn't showcase the conceptual approaches of computational design. Therefore, teaching computational design in landscape architecture requires the reframing of how its methods are used so that the pedological approach shifts away from using it as a goal rather than a tool to realize landscape dynamics as the main driver of the design process.

In this context, the interest in utilizing digital design and fabrication in architecture has been noticeably growing in the middle east and north Africa region. However, there is still a lack of studies on how such technologies are being implemented in respective architectural programs in the regions. In one study by Soliman, Taha, and El Sayad [19], data on twenty international institutes and eight Egyptian institutes were collected and analyzed to identify the status of implementing computer application in architectural curricula within ten subfields; 1) 2D&3D representation 2) BIM 3) Parametric design 4)GIS 5)Digital fabrication 6) Simulation 7) Environmental technology 8) Building technology 9) Communication 10) Coding and Scripting. The study concluded that on the national level (Egypt) digital design and fabrication applications are mostly implemented in the preparatory phases rather than being integrated on a multi-phase among different disciplines as it is found in the international institutes. The study also noted the growing interest among architecture professionals in Egypt towards computational and parametric design tools in practice.

4. SCIAGRAPHY AND PERSPECTIVE IN ARCHITECTURAL EDUCATION: A REGIONAL OVERVIEW

Numerous renowned architects have underscored the significance of light and shadow in the field of architecture. Louis Kahn postulated that the primary function of light is to cast shadows, which serve to evoke a particular ambiance. He contended that a building's plan should be interpreted as a harmony of spaces illuminated by light, and that even spaces intended to be dark should possess sufficient light from an enigmatic aperture to reveal the true extent of their darkness [20]. Le Corbusier maintained that the history of architecture is, in essence, the history of the struggle for light, while Richard Meier asserted that architecture which enters into a symbiosis with light not only creates form in light, both diurnally and nocturnally, but also enables light to become form [21]. Steen Eiler Rasmussen argued that light is of paramount importance in experiencing architecture, and that the same room can convey vastly different spatial impressions simply by altering the size and location of its apertures [22]. Ricardo Legorreta posited that light is intrinsic to both the heart and spirit, attracts individuals, illuminates the path, and when perceived from afar, beckons one to follow it [23].

Sciagraphy education is a crucial course for architects that imparts knowledge on creating accurate and realistic representations of buildings and structures. It is a branch of the science of perspective that deals with the projection of shadows and the delineation of an object in perspective with its gradations of light and shade [24]. In architectural drawing, sciagraphy is the study of shades and shadows cast by simple architectural forms on plane surfaces. The main objective of this course is to teach students graphic techniques and a variety of media to invent or manipulate forms in two or three dimensions. By learning sciagraphy, architects can create drawings that show how light, and shadow interact with buildings, which is essential for creating realistic and accurate designs. Furthermore, sciagraphy education teaches how to use different media, such as pencils, charcoal, ink, and other materials, to create different effects and textures, which results in drawings that are not only accurate but also visually appealing. Another significant aspect of sciagraphy education is that it reinforces the importance of the design studio at school and the culture associated with it. The design studio is where architectural students learn how to create designs, and it is a place where they can collaborate with other students and learn from experienced professors. By learning sciagraphy, architectural students can develop their skills in the design studio and become better designers. The course of sciagraphy and perspective is considered one of the essential and oldest courses that must be included as a part of the design topic. It provides the framework for understanding design by sensitizing students to the conceptual, visual, and perceptual issues involved in the design process.

Sciagraphy is incorporated into architectural education as part of courses dedicated to visual representation, design analysis, or environmental studies. Often, introductory courses in the initial years of architectural education emphasize the importance of comprehending lighting, shadow, and perspective concepts alongside the initiation of design studio coursework. there are several typical approaches employed in universities for teaching sciagraphy. Often, introductory courses in the initial years of architectural education emphasize the importance of comprehending lighting, shadow, and perspective concepts alongside the initiation of design studio coursework. There are several typical approaches employed in universities for teaching sciagraphy. These include providing students with a theoretical foundation on the fundamental principles governing light, shadow, and shading in architecture; teaching various drawing techniques to accurately represent shadows and shading in architectural renderings; encouraging students to observe and analyze the interplay between light and shadow in the built environment; integrating sciagraphy principles into design studio exercises; and incorporating digital tools and software into sciagraphy education.

To gain an understanding of the current state of sciagraphy courses, several syllabus descriptions from regional and international universities were reviewed. The review aimed to gather information on the course description, title, course goals, outcomes, and components (Table 1)

Table 1. Sciagraphy course titles and descriptions in regional and international universities [Authors]

Course title	University	Country	Main Topics (digital design elements in **bold**)
Architectural Presentation [25]	Middle East University	Jordan	-Line drawing and tone drawing -Architectural freehand sketching -Detail elements rendering (plants, trees, shrubs, people, and vehicles) -Graphical representation of buildings (elevation and site plan) -Shade and shadow -Diagraming -Color theory -Watercolor techniques for rendering -Prisma pencils and pastel techniques for rendering -Marker techniques for rendering -Introduction to perspective (one-point and two-point perspective)

			-Layout design for presentations -Basic skills in Photoshop (tools, modification, layout, plan, and elevation) -Final exam/portfolio.
Graphic & Visual Skills 2 [26]	Future University in Egypt	Egypt	-Shadow of Points -Shadow of Points and Lines -Shadow of Planes - Squares -Shadow of Planes on Broken and Curved Planes -Shadow of Planes - Circles -Shade & Shadow of 3D Objects - Pyramids and Cuboids -Shade & Shadow of 3D Objects - Cylinders -Shade & Shadow of 3D Objects - Cuboids, Chimneys, and Cylinders -Shade & Shadow of 3D Objects - Cylinders and Cones -Architectural Applications - Stairs -Architectural Applications - Arches, Niches, and Columns -Architectural Applications - Oculus, Minarets, Pilasters -Two Vanishing Points - Bird's Eye, Ant's Eye, and Exterior Views -Two Vanishing Points Perspective (Pyramids) -Two Vanishing Points Perspective (Cylinders) -Second Midterm Exam -Two Vanishing Points Perspective (Sloped Roofs) -Two Vanishing Points Perspective (Links & Cables) -One Vanishing Point Perspective (Interior) -Final Exam
Shade and Perspective [27]	Mansoura University	Egypt	-Shade and Shadows in Architecture -Basic principles for casting shadows -Casting shades and shadows on different planes -Casting shadows according to the directions of sunrays -Representing architectural forms and spaces -Cone of vision -Vanishing lines for different planes -Distortion in perspectives -One-vanish-point -Two-vanish-point -Shadows in perspectives Determination of measuring
Graphics 2 [28]	Holy Angel University	Philippines	-Basic of Perspectives -Properties of Perspectives and their limitations -One–Point Perspective -Introduction of one-point perspective -One-point exterior -Two-point interior -Measuring Point Perspective -Introduction to measuring point -Normal eye view -Bird’s eye view (aerial view) -Worm’s eye view -Perception of Depth in Perspective Drawing -Casting of Shadows -Vanishing point of light rays; the shadow of a point -Different shading techniques -Shadows of lines and edges -Special Procedures and Techniques -Final Examination

As an example, when examining the Middle East University in Jordan, it was observed that the sciagraphy course is titled "Architectural Presentation." The course description outlines the instruction of diverse skills and techniques utilized in presenting architectural projects through drawings and three-dimensional models, employing various media. The syllabus emphasizes teaching the projection of shades and shadows, as well as one-point and two-point perspectives. The goals and objectives of the course revolve around enabling students to acquire knowledge of drawings that effectively communicate their design ideas and equipping them with proficiency in perspective drawing and representation skills. The course also focuses on teaching construction techniques to facilitate effective visualization and presentation in architectural design.

In contrast, at Future University in Egypt, the sciagraphy course is titled "Graphic & Visual Skills 2." The course description includes topics such as architectural presentation, shade and shadows of different elements (dot, line, surface, volume), shade and shadow of buildings in various representations (plans, elevations, perspectives, and layouts), architectural perspective, and computer simulated perspectives. The primary goals of the course are to enhance students' visualization and representation abilities using scientific methods, apply shade and shadow techniques in architectural representation, and develop skills in drawing perspectives for architectural projects.

In Mansoura university the course is called “Shade and Perspective”. While the specification document offered no formal course description, the course attributes include the utilization of techniques, skills, and appropriate engineering tools for engineering practice and project management, as well as the engagement in self- and lifelong learning. It aims to develop the ability to design robust architectural projects with a combination of creativity and technical mastery. The course also focuses on enhancing investigative skills, attention to detail, and visualization/conceptualization abilities. In terms of knowledge and understanding, the course covers principles of architectural design, including the preparation and presentation of design projects in various contexts, scales, types, and degrees of complexity. It also emphasizes physical modeling, multi-dimensional visualization, multimedia applications, and computer-aided design.

On an international level, the “Graphics 2” course at Holy Angel University in the Philippines aims to achieve several general objectives. In terms of cognitive skills, students will develop an understanding of the importance and applications of perspective, shades, and shadows. They will acquire proficiency in perspective techniques and the ability to identify and illustrate shades and shadows. Additionally, students will recognize the significance of perspective in effective communication with clients and building users, as well as distinguish between two-dimensional and three-dimensional presentations. In terms of psychomotor skills, students will learn to draw perspectives accurately and neatly with speed, following current drafting practices. They will also acquire various presentation techniques that are appealing and easily interpreted in a professional environment. Effective communication through perspective drawings will be emphasized, along with the application of current architectural trends in solutions and presentations. In terms of affective skills, students are expected to complete requirements with interest and accept the challenges of multitasking activities. They will demonstrate effective participation and cooperation within diverse groups and will value sharing ideas to improve drafting approaches. Humility in accepting mistakes and a willingness to improve work will be encouraged.

The reviewed syllabus descriptions of sciagraphy courses exhibit both similarities and differences in terms of their course titles, goals, and components. While the courses share a common focus on architectural presentation and the utilization of shade and shadow techniques, there are variations in the specific topics covered and the emphasis on digital design tools. The course at Middle East University in Jordan emphasizes diverse skills and techniques in presenting architectural projects, with an emphasis on manual drawing and construction techniques and minor part where Photoshop is learned as a digital visualization tool. Future University in Egypt's course, on the other hand, includes computer simulated perspectives and highlights the application of scientific methods. Mansoura University's course, named "Shade and Perspective," emphasizes the utilization of appropriate engineering tools and computer-aided design, while Holy Angel University's "Graphics 2" course emphasizes the importance of perspective, shades, and shadows in effective communication and incorporates current architectural trends and digital drafting practices.

5. STATUS QUO OF SCIAGRAPHY AND PERSPECTIVE COURSES IN UNIVERSITY ARCHITECTURAL EDUCATION IN EGYPT

To comprehensively investigate the current landscape and test the study's hypothesis, an online survey was conducted to evaluate the prevailing state and substance of Sciagraphy and Perspective courses within university education. Additionally, the survey aimed to explore the implications and extent of integrating digital design and fabrication tools into the courses' syllabi. The targeted respondents encompassed university teaching staff, ranging from esteemed Professors to dedicated Teaching Assistants, all actively engaged in imparting these specialized courses. Ethical procedures were adhered to, encompassing the acquisition of informed consent from all participants before submitting their responses. Furthermore, the study was conducted with the requisite institutional permissions and guidelines of the authors' institution in place to ensure full compliance with ethical standards.

The survey was distributed in an online format, and potential participants were contacted via email invitations and through public announcements on social networks within the authors' extended professional network. A total of 36 valid responses were received, representing a diverse range of positions and universities. Participants' institutions encompassed a wide variety of universities both within and outside Egypt, including Cairo University, Helwan Al-Materia University, Faculty of Fine Arts in Helwan University, Port Said University, Ismailia University, Badr University, Al-Ahram Canadian University, Misr International University, Assiut University, Banha University, the British University in Egypt, and Al-Mansoura University. Additionally, responses were received from regional universities such as King Salman University, Princess Nora University in Riyadh, Dar Al-Uloom University, and Effat University.

Figure 3: Respondents distribution across university positions [Authors]

The distribution of participants' positions in the study reveals a diverse representation among academic ranks. Lecturers (Assistant Professors) make up the largest proportion at 25.0%, closely followed by Teaching Assistants at 22.2%. Assistant Lecturers, Associate Professors, and Professors contribute significantly to the sample as well, each comprising around 16.7% (Figure 3). Regarding the frequency of instructional engagement, the data revealed that 19.4% of the respondents reported their involvement in these courses every semester, 33.3% engaged once a year, and 47.2% participated once every few years (Figure 4). Regarding the structural arrangement of the course syllabus, 14 out of 36 respondents (38.9%) indicated that their respective institutions offered the course as a unified course, while 15 out of 36 (41.7%) reported that it was separated into two distinct modules. Additionally, 7 out of 36 respondents (19.4%) mentioned that their institutions had more than two modules for the course (Figure 5). In terms of class size, the new data reveals that 2 out of 36 participants (5.6%) mentioned class sizes of less than 10 students, while 1 out of 36 (2.8%) reported class sizes ranging from 10 to 20 students. A significant majority of 19 out of 36 participants (52.8%) cited class sizes between 20 and 30 students. Furthermore, 3 out of 36 (8.3%) mentioned class sizes ranging from 40 to 50 students, and 11 out of 36 (30.6%) reported having more than 50 students in these courses (Figure 6).

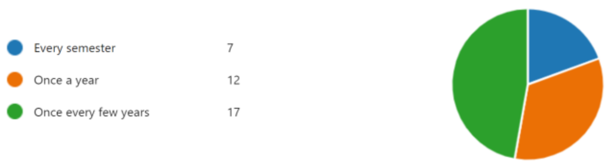

Figure 4: responses to the survey question "How often are you involved in teaching Sciagraphy and Perspective courses?" [Authors]

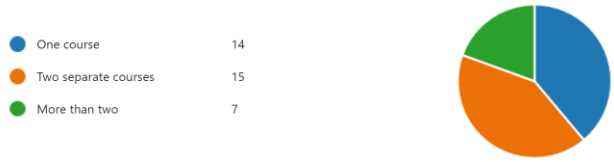

Figure 5: responses to the survey question "At your institution, how many courses pertaining to sciagraphy, perspective, and manual sketching are currently offered?" [Authors]

Figure 6: responses to the survey question "On average, how many students enroll in the course pertaining to sciagraphy and perspective in a single academic term at your institution?" [Authors]

The survey dealt with several questions aimed at understanding the prevailing practices in teaching Sciagraphy courses and how the teaching staff delivered learning materials, as well as their approach to updating the course syllabus to align with advancements in technology. In response to a question about the frequency of course updates, the new data shows that 6 out of 36 respondents (16.7%) mentioned that the course was mostly not updated. Additionally, 22 out of 36 respondents (61.1%) reported updating the course every few years, while 7 out of 36 respondents (19.4%) indicated updating it annually. Only 1 out of 36 respondents (2.8%) reported updating the course every semester (Figure 7). In terms of the instructional materials primarily employed for course delivery, the data analysis reveals distinct preferences among respondents. Visual aids, including slides, images, and videos, emerged as the most selected materials. Following closely behind were handouts and lecture notes, while the utilization of white/blackboards ranked third in popularity. Online tutorials and resources were the fourth most preferred choice, with textbooks and reference books coming fifth. Notably, the integration of software applications for digital rendering and visualization in teaching was among the least preferred options chosen by the respondents (Figure 8).

Figure 7: responses to the survey question "What is the frequency of updates to the course contents at your institution?" [Authors]

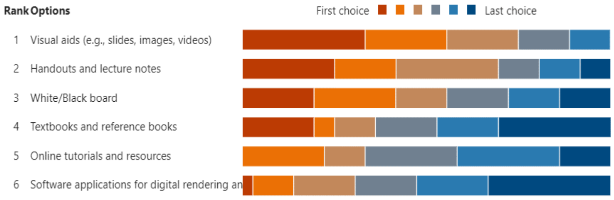

Figure 8: responses to the survey question "What instructional materials or resources do you use to teach sciagraphy and perspective? (Rank from most to least)" [Authors]

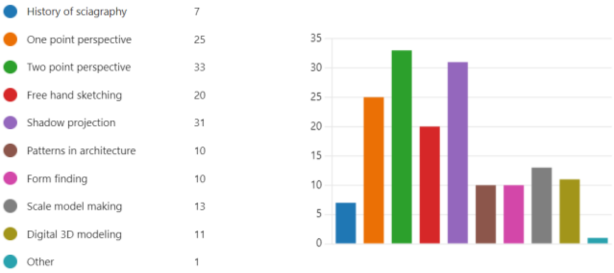

Figure 9: responses to the survey question "What are the principal constituents comprising the sciagraphy and perspective course?" [Authors]

In response to the survey question about the principal constituents of the sciagraphy and perspective course, participants highlighted the predominant elements as follows: One-point perspective was cited by 69.4% of respondents, while two-point perspective was noted by 90.7%, and shadow projection by 86.1%. Other prominent components included freehand sketching (55.6%), scale model making (36.1%), and digital 3D modeling (30.6%). History of sciagraphy was mentioned by 19.4% of respondents, patterns in architecture and form finding by 27.8% each, and "Other" components, not specified, were mentioned by 2.8% of participants. These findings provide insights into the core components that make up the sciagraphy and perspective course, emphasizing the prevalence of perspective techniques and shadow projection as key topics within the curriculum (Figure 9).

The survey encompassed several inquiries aimed at gauging the perceptions of the teaching staff (Figure 10). These questions were assessed using the Net Promoter Score (NPS) methodology, which categorizes respondents into "promoters," "passives," and "detractors" based on their ratings [29]. The survey results reveal a diverse range of attitudes and perceptions among respondents on several key topics. While respondents showed a relatively neutral level of acquaintance with terms like "Digital Design" and "Digital Fabrication" (NPS SCORE: -8), there was a notable consensus that fundamental teachings in perspective and shadow projections remain imperative (NPS SCORE: 17). The question regarding the need for adherence to the current state or substantive modifications received a positive average sentiment (NPS SCORE: 8), suggesting openness to adaptation. However, respondents leaned towards retaining the course's individual identity rather than assimilating it into a cluster of related courses (NPS SCORE: -19). The relevance of digital design and fabrication techniques in sciagraphy and perspective courses yielded a neutral perception (NPS SCORE: 0), indicating a balance of views. Notably, the integration of these techniques in these courses garnered a significantly negative sentiment (NPS SCORE: -47), indicating a widespread belief that more integration is needed. Overall, the results highlight the complexity of perspectives within the survey sample, with varying degrees of support for the integration of digital techniques and potential adaptations to the curriculum.

The survey results regarding the integration of the Sciagraphy course with other architectural curriculum courses indicate a clear consensus among respondents. An overwhelming 32 out of 36 participants (88.9%) identified "Architectural Design Studio" as the most pertinent choice for integration, underscoring its paramount significance in architectural education. While other courses received varying degrees of support, the preferences were notably less pronounced. Specifically, "Computer Applications in Architecture" garnered support from 22 respondents (61.1%), highlighting its potential synergy with Sciagraphy. "Interior Design" also received notable attention, with 18 respondents (50.0%) recognizing its relevance for integration. In contrast, "Architectural History & Theories," "Urban Planning and Design," "Sustainable Design and Green Building," "Landscape Architecture," and "Other" courses received fewer mentions, ranging from 2.8% to 22.2%. Notably, "Building Technology," "Building Codes and Regulations," and "Housing" did not receive any mentions as preferred choices for integration (Figure 11). In response to the question concerning the incorporation of specific digital tools into the Sciagraphy and Perspective course, a notable preference was observed among respondents for their 1st, 2nd, and 3rd choices. "Simple shadow study tools" like SketchUp were the most favored, with 13 respondents (36.1%) selecting it as their 1st choice, and a total of 20 respondents (55.6%) choosing it among their top three preferences. More advanced 3D modeling tools such as 3D Max and others closely followed in the second position, with 9 respondents (25.0%) selecting them as their 1st choice and 24 respondents (66.7%) including them in their top three preferences. In contrast, digital fabrication tools like laser cutters, CNC machines, and 3D printers were among the least selected options, with only a total of 7 respondents (19.4%) choosing these tools among their top three preferences. This suggests a potential gap in awareness or recognition of the potential applications of digital fabrication tools in the course (Figure 12). The survey responses regarding the challenges of integrating digital tools into Sciagraphy courses reveal a consensus on the top three obstacles. Firstly, "Balancing Traditional and Digital Approaches," with 22 responses, emerges as the most prevalent challenge, indicating the importance of maintaining equilibrium between conventional techniques and digital tools (61.1% of respondents). This suggests that educators must carefully consider how to strike this balance to ensure effective pedagogy. "Learning Curve" follows closely, with 19 respondents recognizing the challenge students and instructors may face when adapting to new software or hardware (52.8% of respondents). This emphasizes the need for robust training and onboarding processes. "Access and Infrastructure" ranks third, highlighting the need to ensure that students have the necessary tools and reliable internet access (36.1% of respondents). These findings underscore the multifaceted nature of implementing digital tools in the context of Sciagraphy courses and highlight the significance of addressing these challenges comprehensively to ensure successful integration (Figure 13).

To what degree are you acquainted with the terms "Digital Design" and "Digital Fabrication"?

To what extent do you believe that it remains imperative to impart fundamental teachings in perspective and shadow projections?

To what degree do you believe it ought to adhere to the current state or necessitate substantive modifications for adaptation?

do you believe that it is more advantageous for the course to retain its individual identity as a standalone course or to be assimilated into a cluster of interconnected courses that are thematically related?

To what extent do you perceive the relevance of employing digital design and fabrication techniques in the context of sciagraphy and perspective courses?

To what extent do you currently integrate digital design and fabrication techniques in the context of sciagraphy and perspective courses?

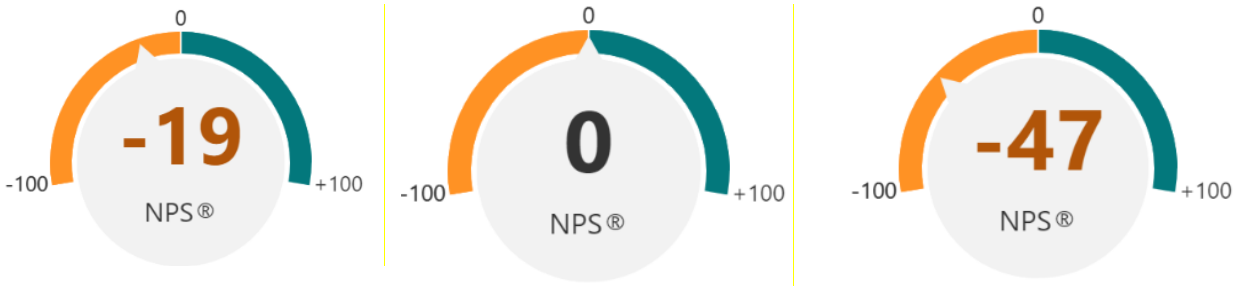

Figure 10: NPS scores reflecting opinions on topics for developing more up to date sciagraphy courses. [Authors]

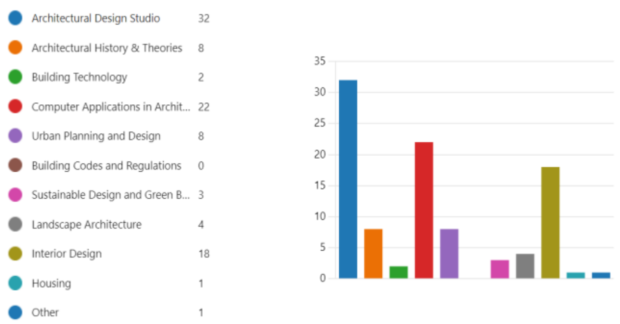

Figure 11: responses to the survey question "In the scenario where the course is to be integrated with other courses within the architectural curriculum, which specific courses would demonstrate the utmost pertinence for such integration? (Select top three courses)" [Authors]

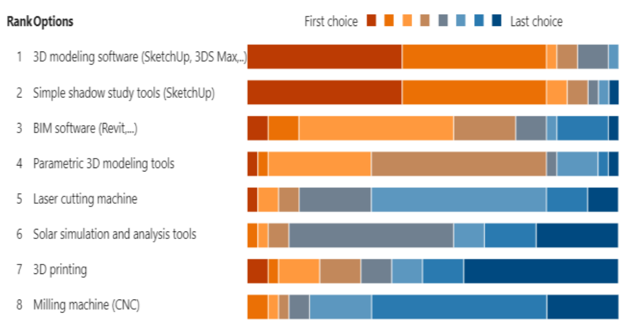

Figure 12: responses to the survey question "Among the array of digital tools available, which specific tool do you deem the most promising for integration into the sciagraphy and perspective course? (Rank from most to least)" [Authors]

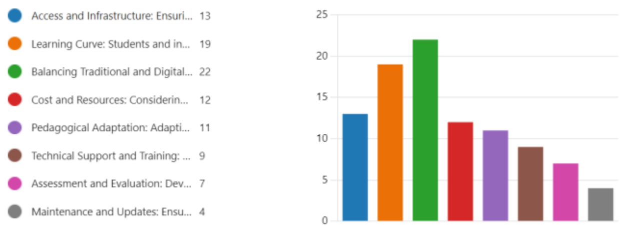

Figure 13: responses to the survey question "What do you think the challenges facing more integration of such digital tools in Sciagraphy courses? (Select top three reasons)" [Authors]

6. METHODOLOGY

The proposed hybrid course curriculum, encompassing the integration of digital design techniques with traditional manual techniques, has been successfully implemented across three prominent Egyptian universities: Badr University, Ahram Canadian University, and Suez Canal University. These institutions represent private and public universities, showcasing the broad applicability of the curriculum across diverse academic settings. The implementation of the hybrid course occurred at the first-year level of architectural education during the fall semester. This placement ensures that students are introduced to the course early on in their academic journey, allowing them to acquire foundational skills and knowledge that will serve as building blocks for their future architectural studies. The student cohorts in each university varied slightly in size. Suez Canal University accommodated an average of 30 students, while Al Ahram had an average of 55 students, and Badr University had an average of 48 students. This diverse range of student populations provided a comprehensive testing ground for the curriculum, enabling an evaluation of its effectiveness across different class sizes and institutional contexts. Throughout the 13-week duration of the course, students engaged in a series of classes, combining lectures and tutorials facilitated by teaching assistants.

The curriculum encompassed a total of 3 credit hours, with 1 credit hour dedicated to lectures and 4 credit hours allocated for tutorial sessions. This distribution allowed for a balanced emphasis on theoretical knowledge acquisition and hands-on practical exercises, ensuring that students received a comprehensive educational experience. As a fundamental course in early architectural education, this hybrid curriculum provided students with a solid foundation in sciagraphy and perspective studies. Although the course titles may have slightly varied between institutions, such as "shadow and perspective" or "sciagraphy and perspective," the content and course outcomes remained consistent across all universities. The course content explored the interplay of light, shadow, and three-dimensional space, while the outputs aimed to foster students' ability to comprehend and effectively utilize these concepts in their architectural design work. Despite minor variations in terminology, the course structure and objectives were consistent across all three universities. This uniformity allowed for a cohesive learning experience, ensuring that students obtained comparable knowledge and skills regardless of their institution of study.

The proposed course was structured into four progressive levels throughout the semester. Each level was designed to facilitate a seamless advancement of students' knowledge and skills (Figure 14). Level 1 served as the foundation, focusing on developing visual thinking through fundamental exercises (Figure 15), projections, and manual sketches, essential for architectural representation. Moving on to Level 2, students were introduced to digital techniques, starting with basic tools like SketchUp for shadow analysis, while still incorporating traditional manual approaches in creating scale models of architectural forms. This level acted as a bridge, allowing students to adapt to digital tools while building upon their fundamental skills.

Level 3 represented a further advancement in digital proficiency, as students explored laser cutter scale models and the intricate interplay of light and shadow in architectural design. This stage marked a significant step towards mastering digital tools for precise representation and analysis. Finally, Level 4 culminated in the mastery of advanced digital design and fabrication tools. Students utilized 3D printing and parametric design plugins in SketchUp to create intricate architectural models and dynamic, innovative concepts. This advanced level equipped students with cutting-edge skills, preparing them to push the boundaries of architectural expression and embrace technological integration. Throughout each level, the course emphasized experiential learning, empowering students to continuously refine their ideas and reimagine their designs. They gained a nuanced understanding of how architectural elements influenced shadow formations and spatial perception, enhancing their ability to create visually compelling and contextually responsive designs.

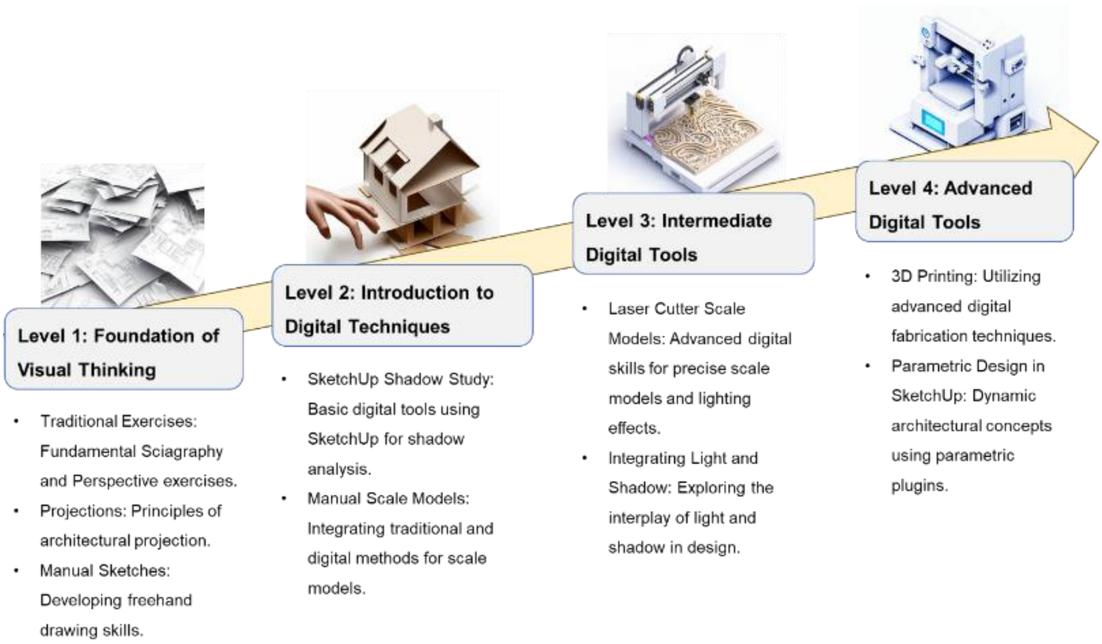

Figure 14: Levels of Progression in using digital design tools the proposed Sciagraphy and Perspective course [Authors]

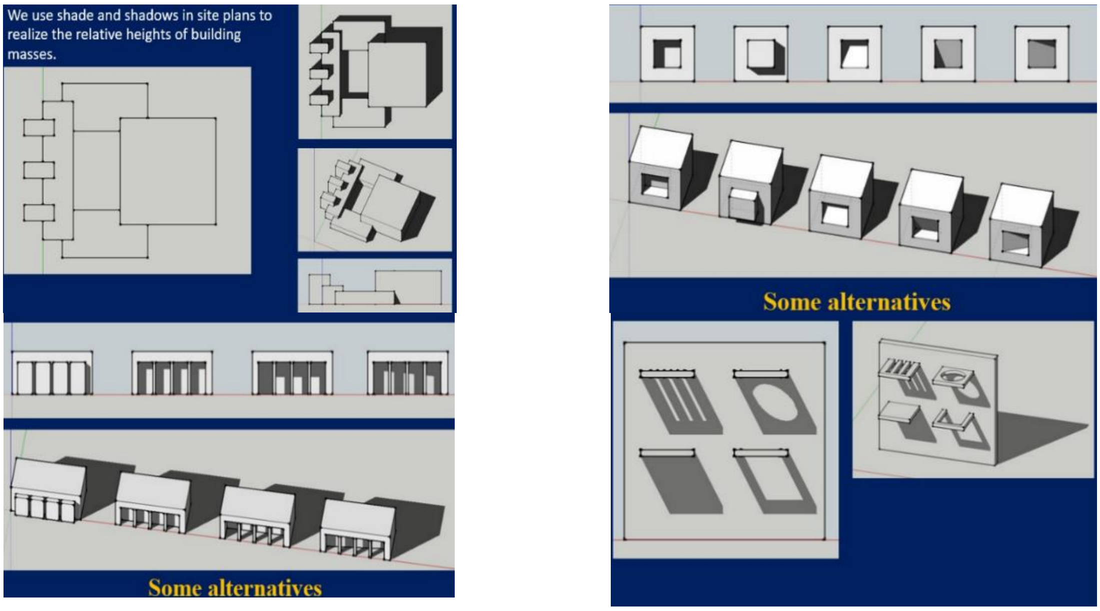

Figure 15: Examples of shadow studies and exercises aim to kickstart students' visual thinking and imagination in the third dimension by enhancing their understanding of shadows [Authors]

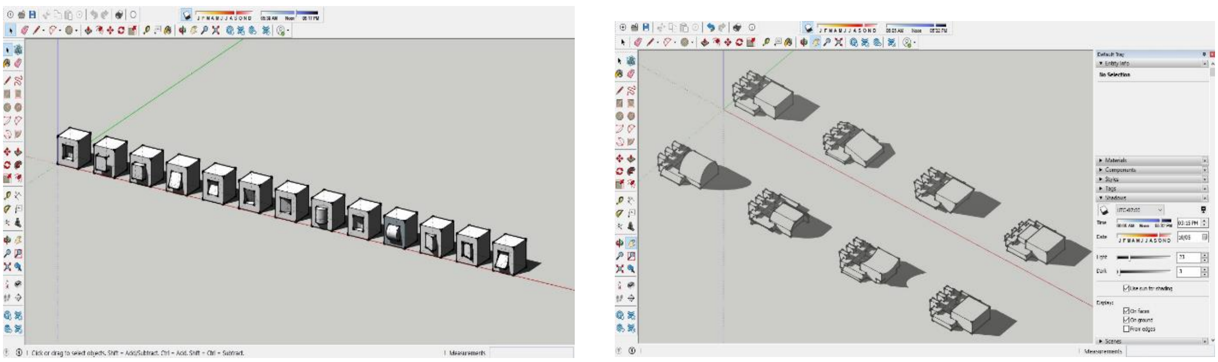

Figure 16: Examples of the "Square in Square" visual exercise in SketchUp software using the realistic shadow simulator tool [Authors]

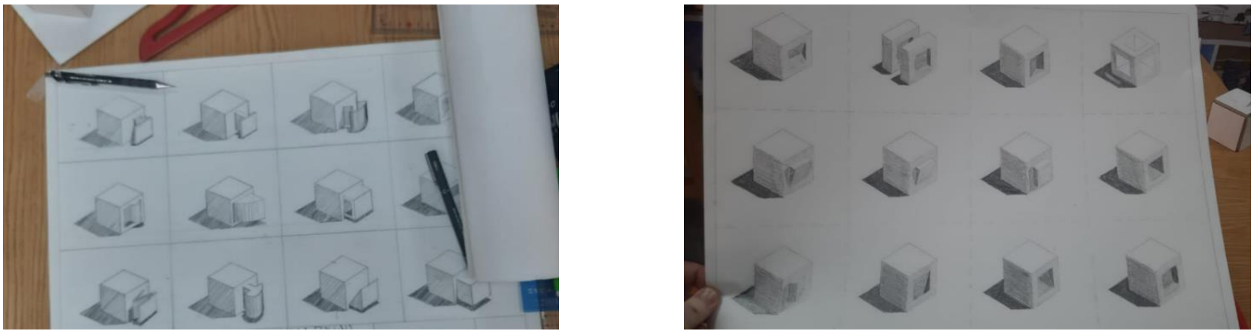

Figure 17: Examples of students' hand sketches for form composition studies and shadow projection [Authors]

Figure 18: Handmade scale models crafted by the students to study the shadow composition in forms derived from the 3D shadow studies conducted in SketchUp [Authors]

Notably, SketchUp offered a native engine for sun simulation and shadow studies, allowing students to explore theoretical approaches and projection-based learning related to shade and shadow calculations for different geometries and temporal attributes. Moreover, SketchUp facilitated integration with digital fabrication tools such as 3D printers, laser cutters, and CNC machines, enabling students to bridge the gap between digital modeling and physical realization. The straightforward and intuitive nature of SketchUp's form-finding processes, predominantly based on push/pull operations, contributed to a rapid learning curve among students. This expeditious grasp of the software's fundamentals fostered student engagement and proficiency. As a result, students effectively utilized SketchUp to explore architectural design concepts, analyze solar impacts, and seamlessly translate their digital designs into physical prototypes. The incorporation of SketchUp into the course framework enriched the students' learning experience, providing a comprehensive understanding of digital design tools and their practical applications in architectural practice.

At this level of instruction, SketchUp served as a valuable tool for form finding exercises, enabling students to translate 2D elevations into 3D geometries using their imaginative capacities. An early exercise involved the "square in square" problem (Figure 16), where students were tasked with envisioning 3D geometries that would yield the same square in square 2D elevation. Drawing upon their imagination, students explored recessed or cantilevered elements, curved or sloped geometries, and other variations to construct these elevations. The study of shade and shadow, coupled with its role in form finding within three-dimensional space, significantly influenced the students' imaginative processes. Building upon these foundational exercises, students progressed to more advanced compositions. For instance, they tackled the challenge of visualizing groups of rectangles in perspective and employing shade and shadow techniques learned in SketchUp to depict how these compositions would appear in 3D. Throughout the course, multiple workshops were conducted by the teaching assistants and the lecturer, covering various interconnected themes. Students engaged in activities centered around shade and shadow basics, perspective fundamentals, modeling, and shadow manipulation in freehand drawing (Figure 17), and manual scale model techniques (mockups) (Figure 18 and Figure 19). They also delved into exercises related to façade fenestration, which involved printing façade patterns using CNC machines and creating mockups for sun and shadow pattern analysis (Figure 20).

Moreover, the course incorporated a segment where students synthesized their accumulated knowledge by designing parametric masses to maximize shading effects and enhance design aesthetics. These parametric models were then brought to life using advanced 3D printing techniques, enabling students to physically realize their designs (Figure 21). Collaboration played a vital role during the parametric modeling and 3D printing stages, as students worked in groups to emphasize participatory values in design and enrich the final output through the collective input of each student. This collaborative approach fostered a sense of unity and competitiveness among the students. Throughout each stage of the course, the teaching assistant staff provided guidance and support, ensuring that students received the necessary assistance to navigate the challenges and complexities of the assignments. The combination of hands-on digital modeling, manual scale models, freehand drawing, CNC printing, parametric design, and 3D printing formed a comprehensive learning experience that integrated both technological tools and traditional techniques. This holistic approach nurtured students' creativity, problem-solving skills, and collaborative abilities, equipping them with a diverse skill set essential for their future endeavors in architectural design.

Figure 18: Handmade scale models crafted by the students to study the shadow composition in forms derived from the 3D shadow studies conducted in SketchUp [Authors]

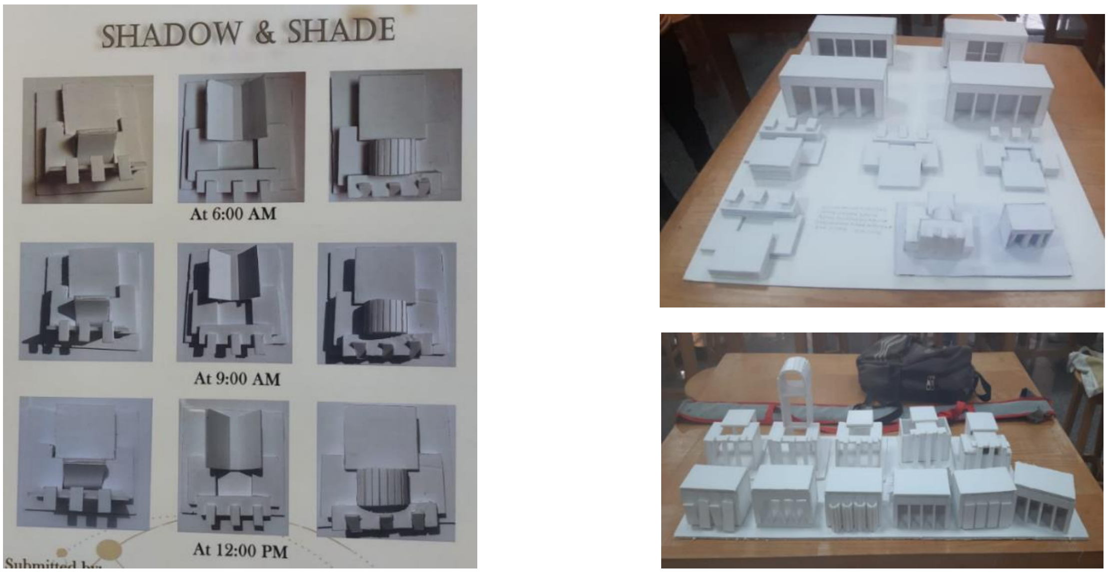

Figure 19: Examples of shadow studies conducted on handmade scale models [Authors]

Figure 20: Examples of laser-cut fenestration pattern scale models and their perspective shadow studies in natural light. (Representative sample) [Authors]

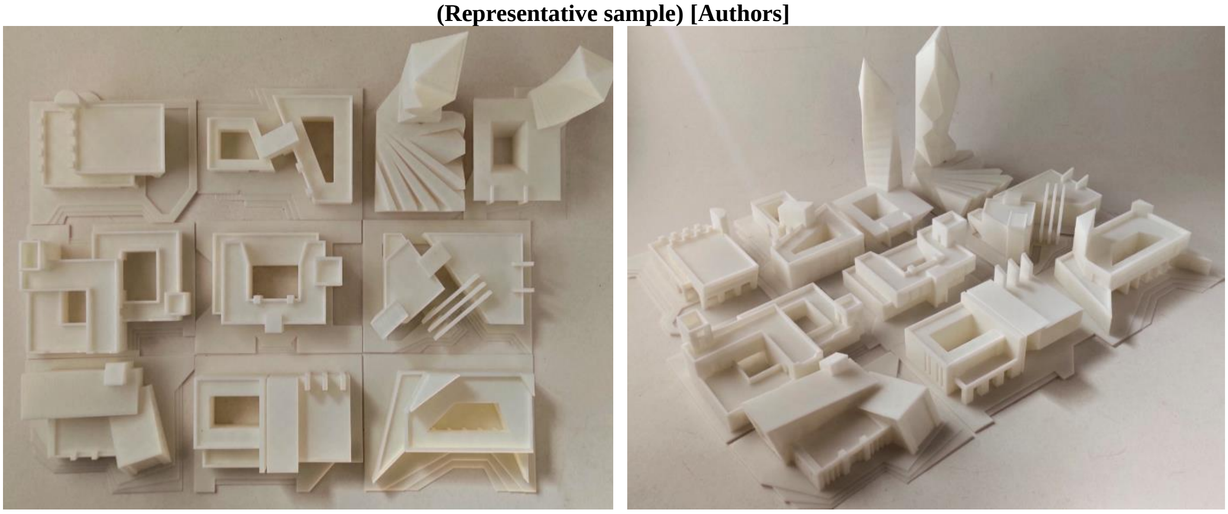

Figure 21: Examples of the final outputs of students using parametric design tools in SketchUp, coupled with 3D printing techniques, reflect a profound understanding of the value and impact of shadow and light in form finding and overall form composition [Authors]

The course followed a working style that initially emphasized individual output, allowing each student to explore their critical thinking and improve their manual hand drawing skills. During these early stages, students submitted their individual work, enabling them to delve into architectural formation and exercise their creativity. As the course progressed, students advanced to designing parametric forms, where they were encouraged to expand their awareness of 2D shapes and translate them into three-dimensional structures. This flexibility in using 3D modeling tools allowed students to brainstorm ideas, supported by manual freehand drawing sketches, as they contemplated the desired output geometry. The final output masses, which emerged at the conclusion of the course, served as tangible evidence of the students' learning process in envisioning three-dimensional architectural forms through the manipulation of simple primitive geometries. Guided by a given land usage area and design brief, such as a residential or office building with a tower and podium, students embarked on a journey to create the required forms and perspectives while considering the impact of shade and shadow. Integration of other course components occurred using firsthand sketches and point projections to calculate shadows for the proposed forms. Students then reimagined these forms digitally, enabling them to understand the effect of light and shadow on the overall design and gain insights into projection and elevation outputs derived from the 3D form.

In their exploration of shadows cast by their own forms, students examined the variations in shadow shape and patterns resulting from inclination, right-angle extrusions, recesses, and projected forms. They learned to produce rich shadow patterns by strategically manipulating the design elements. Throughout this process, students acquired a deeper understanding of the interplay between light, shadow, and form, honing their perceptual and analytical skills. By integrating firsthand sketches, manual drawings, and digital modeling, students engaged in a comprehensive learning experience that bridged the gap between traditional and digital design techniques. This working style fostered a dynamic and iterative design process, where students continually refined their ideas and reimagined their forms to optimize the interplay of light and shadow. Through experimentation and exploration, students developed a nuanced understanding of how architectural elements influenced shadow formations and spatial perception. This hands-on approach cultivated their ability to create visually compelling and contextually responsive designs, preparing them for the multifaceted challenges they might encounter in their future architectural endeavors.

An investigation was undertaken to evaluate the efficacy of the course's instructional techniques and structure in facilitating a successful learning experience and skill development. A post-course survey was administered to students who had enrolled in the hybrid course, aiming to gain insights into their impressions, perceptions, and overall satisfaction with the instructional methods. The survey also sought to ascertain students' future directions in design and their perceptions of potential enhancements to the course. The questionnaire was distributed to a representative sample of course participants, yielding general insights from their responses. One of the survey items inquired, "How effectively did the course in sciagraphy and perspective enhance your understanding of shadow and light in architectural design " The results indicated a prevailing agreement among respondents that the course significantly improved their comprehension of shadows and perspectives as both a conceptual framework and a practical application. On a scale of 1 to 10, 41 percent of the participants awarded a score of 8, followed by 27.6 percent who responded with a score of 9 (**Figure 22**).

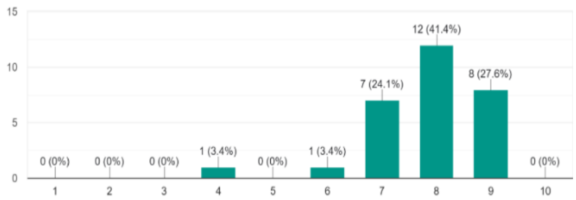

Figure 22: respondent's answer to the question "How effectively did the course in sciagraphy and perspective enhance your understanding of shadow and light in architectural design?" 1 is not at all, 10 is yes very much [Authors]

Furthermore, when asked about the degree to which the course met their expectations regarding the practical application of sciagraphy and perspective concepts in architectural design, approximately 45 percent of respondents rated it an 8, and 24 percent rated it a 9 (**Figure 23**). Regarding form finding and the architectural design studio, participants were asked to assess the extent to which the course enhanced their ability to create visually compelling architectural forms using sciagraphy and perspective techniques. Approximately 36 percent of respondents assigned a score of 8, and a vast majority expressed a positive sentiment regarding the improvement of their form-finding skills after completing the course (**Figure 24**). Moreover, the course received predominantly positive ratings in terms of how effectively it bridged the gap between traditional and digital methods in form finding, as perceived by the students, with 32 percent assigned a score of 10 (very successful) (**Figure 25**).

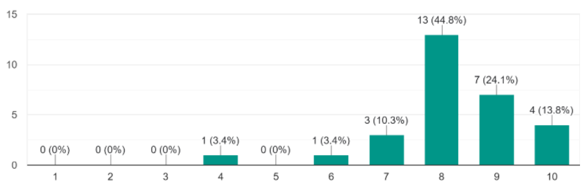

Figure 23: respondent's answer to the question "To what extent did the course meet your expectations regarding the practical application of sciagraphy and perspective concepts in architectural design?" 1 is Fell Short of Expectations, 10 is Exceeded Expectations [Authors]

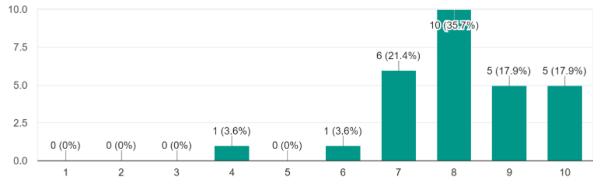

Figure 24: respondent's answer to the question "Please rate the extent to which the course improved your skills in creating visually compelling architectural forms using sciagraphy and perspective techniques". 1 very ineffective, 10 is Very effective [Authors]

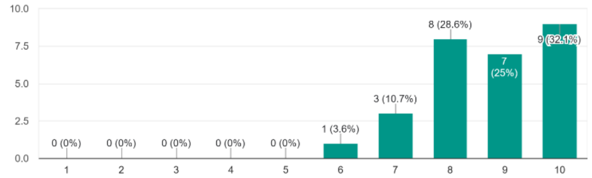

Figure 25: respondent's answer to the question "How successful was the course in bridging the gap between traditional manual drawing techniques and digital tools for designing architectural forms?" 1 is Unsuccessful, 10 is Very Successful [Authors]

Regarding the preferred approach to architectural design after completing the course, a significant majority of students (31 percent) expressed a strong inclination towards integrating both manual and digital methods, assigning a score of 10 on the scale (**Figure 26**). This suggests a prevailing trend among the respondents in favor of adopting a balanced use of traditional and digital tools in their design processes. When asked about the most beneficial tools they learned during the course, 51 percent of respondents highlighted 3D printing as the most advantageous. Modeling in SketchUp and creating scale models were also deemed highly beneficial, each receiving approximately 45 percent of the responses (**Figure 27**).

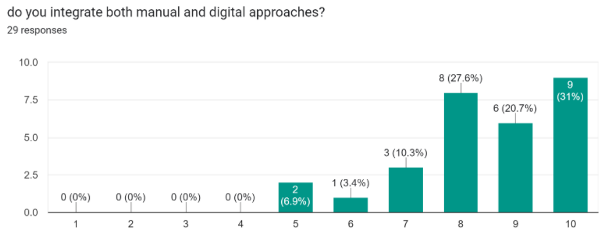

Figure 26: respondent's answer to the question "After taking the course, are you solely inclined to utilizing digital tools in your architectural design, or do you integrate both

manual and digital approaches?" 1 is Solely Digital Tools, 10 is Integrate both Manual and Digital [Authors]

In terms of future improvements to the course, the students' opinions were clear. A substantial 62 percent of surveyed students expressed the desire for the integration of more advanced digital design tools, such as Grasshopper and Rhino, into the course syllabus. They also emphasized the importance of revising the final exam format to align with the digital tools taught during the course. Currently, the final exam is administered in a paper-based format, which they feel does not adequately reflect their acquired digital design skills. Furthermore, approximately 58 percent of the students expressed the need for additional workshops and resources within the course to further enhance their proficiency in digital design (**Figure 28**). This highlights the students' keen interest in developing their abilities and indicates the potential for expanding the course's offerings to better meet their aspirations.

Figure 27: respondent's answer to the question "Among the skills taught in the course, please select the top three that you found most beneficial in enhancing your understanding and application of sciagraphy and perspective in architectural design" [Authors]

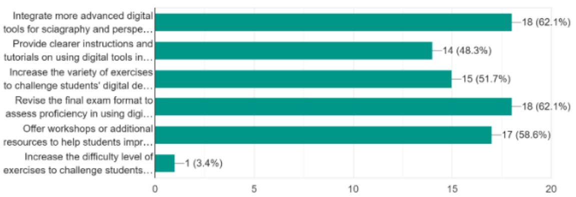

Figure 28: respondent's answer to the question "Based on your experience, what improvements or changes would you recommend enhancing the course for future students?" [Authors]

7. DISCUSSION

This paper presented a case study that focused on the development of a course for new students in the field of architecture, aimed at integrating digital tools and technology into traditional subjects such as sciagraphy. The significance of acquiring fundamental skills and understanding projection techniques to foster creativity was emphasized throughout the study. The course was designed to establish a hybrid and integrative framework for architectural education, combining traditional elements with digital design and fabrication tools, as well as providing training in design thinking, aesthetics, and form-finding skills. However, limitations were acknowledged, particularly regarding the requirement of a written, paper-based final exam format, which posed challenges in fully implementing the hybrid approach during assessment. The findings underscored the need for updated course structures and assessment methods that align with the objectives of a hybrid architectural education, ensuring students are equipped with a diverse skill set relevant to the digital age.

The results of the online survey provide valuable insights into the current landscape of Sciagraphy and Perspective courses within university education and shed light on the implications of integrating digital design and fabrication tools into these courses. The participant cohort primarily consisted of teaching assistants, assistant lecturers, and lecturers actively engaged in imparting these specialized courses. The results suggest that while there is a familiarity with digital design and fabrication concepts among teaching staff, there is a need for greater recognition of the potential benefits and applications of digital tools in Sciagraphy and Perspective courses. The survey findings also highlight the importance of striking a balance between traditional and digital approaches in architectural education. Addressing the challenges identified, such as providing technical support and training and developing appropriate evaluation criteria for work created with digital tools, may pave the way for more effective integration of digital design and fabrication techniques into architectural education.

The results of the post-course survey on the hybrid Sciagraphy and Perspective course provide valuable insights into its effectiveness in facilitating a successful learning experience and skill development among students. Interestingly, a prevailing trend among students was the preference for integrating both manual and digital approaches in their architectural design after completing the course. This suggests that students recognize the value of using a combination of traditional and digital tools to enhance their creativity and problem-solving abilities. The course's emphasis on balancing manual and digital techniques appears to have influenced students' design mindset positively, fostering adaptability and openness to diverse design approaches. Regarding specific tools taught in the course, 3D printing was highlighted as the most advantageous by the majority of respondents. This implies that students see the potential of modern digital fabrication technologies to revolutionize architectural design processes.

The recognition of 3D printing as a valuable tool underscores the increasing importance of digital tools in contemporary architectural practice. The survey results also revealed that students expressed a desire for the integration of more advanced digital design tools, such as Grasshopper and Rhino, into the course syllabus. This indicates their eagerness to explore more sophisticated software and techniques to further enhance their digital design skills. It also suggests that the course successfully sparked students' curiosity and interest in deeper exploration of digital design possibilities. Additionally, students expressed a need for revising the final exam format to better align with the digital tools taught during the course. This reflects their desire for assessments that effectively evaluate their acquired digital design abilities. Moreover, students emphasized the importance of additional workshops and resources within the course to further enhance their proficiency in digital design. This highlights their commitment to continuous learning and improvement in digital design practices.

In addition, the integration of digital evolution in architecture and the rise of generative artificial intelligence (AI) in sciagraphy and perspective courses offers enhanced creativity, efficiency, and informed decision-making. It enables students to explore diverse design possibilities, make data-driven choices, and respond flexibly to changing project requirements. Additionally, it promotes sustainability integration, prepares graduates for industry demands, encourages interdisciplinary collaboration, and empowers future architects to embrace technology as a valuable tool in architectural expression.

Moving forward, it becomes paramount to navigate this transitional phase with caution and mindfulness. An equilibrium must be sought, where the integration of technology aligns harmoniously with the preservation of fundamental architectural skills and the cultivation of students' innate imaginative abilities. This balance will empower the next generation of architects to confidently navigate a rapidly evolving professional landscape while preserving the essence of architectural craftsmanship. It is evident that the journey towards harmonizing manual practices with digital methodologies is an ongoing process. Efforts to equip both educators and students with the necessary skills and tools should be continuous and dynamic, ensuring that architectural education remains relevant and effective in preparing graduates to address the challenges and opportunities of the ever-changing architectural field.

8. CONCLUSIONS

This research presents a case study that explores the integration of digital design techniques with traditional manual methods in a novel hybrid course curriculum on sciagraphy and perspective studies. By implementing this curriculum in three Egyptian universities, the study successfully introduces innovative digital tools and methods for sciagraphy and perspective education, such as 3D form modeling and in-depth studies of shadows and shading. The course's objectives, which focus on enhancing students' imaginative abilities, form generation skills, appreciation of the significance of shadows, expression of ideas through shadow, and capacity to explore diverse design alternatives, were effectively addressed through this integrated approach. The significance of this research lies in its contribution to the advancement of architectural education. By introducing a framework for integrating digital tools into traditionally taught courses, this study validates the effectiveness of such techniques in the learning and skill acquisition process. The positive student outcomes demonstrated the value of merging traditional and digital methods, creating a more holistic and enriched learning experience.

The successful implementation of this hybrid curriculum indicates its potential applicability beyond the context of the case study. The insights gained from this research can be extrapolated and adapted to benefit architectural education in other Egyptian and regional universities. By embracing these innovative approaches to teaching sciagraphy and perspective, educational institutions can better equip students to meet the demands of a rapidly evolving architectural profession. As architectural design continues to evolve, integrating digital technologies becomes increasingly essential for the preparation of future architects. This research opens new avenues for curriculum development, encouraging educators to adopt similar hybrid approaches that foster creativity, technical proficiency, and adaptability to the changing landscape of architectural practice. Nonetheless, further research and evaluation are required to continuously refine and optimize the hybrid curriculum. Understanding the long-term impacts and continued effectiveness of this integrated approach will be essential for the sustainable improvement of architectural education.

9. REFERENCES

[1] Buildner, “4 Simple Concepts of Prehistoric Architecture,” 2023. https://architecturecompetitions.com/4-simple-concepts-of-prehistoric-architecture/ (accessed Jul. 17, 2023).

[2] M. Chakraborty, “Designing Better Architecture Education: Global Realities and Local Reforms,” Copal Publishing Group, 2015.

[3] S. Avsec and M. Jagiełło-Kowalczyk, “Investigating Possibilities of Developing Self-Directed Learning in Architecture Students Using Design Thinking,” *Sustainability*, vol. 13, no. 8, Art. no. 8, Jan. 2021, doi: 10.3390/su13084369.

[4] A. Bridges, “A Critical Review of Problem Based Learning in Architectural Education,” in Communicating Space(s) [24th eCAADe Conference Proceedings / ISBN 0-9541183-5-9] Volos (Greece) 6-9 September 2006, pp. 182-189, CUMINCAD, 2006. Accessed: Jun. 12, 2023. [Online]. Available: https://papers.cumincad.org/cgi-bin/works/paper/2006_182

[5] S. Doyle and N. Senske, “Between Design and Digital: Bridging the Gaps in Architectural Education,” Charrette, vol. 4, no. 1, pp. 101–116, Apr. 2017.

[6] M.-A. G. Gallas, K. Jacquot, S. Jancart, and F. Delvaux, “Parametric Modeling: An Advanced Design Process for Architectural Education,” presented at the eCAADe 2015, Sep. 2015. Accessed: Jun. 12, 2023. [Online]. Available: https://hal.science/hal-02890293

[7] H. T. Putro and L. S. Pamungkas, “Parametric Design In Phase Of Schematic Design Case Study: Student Creativity On Form Studies,” presented at the 18th International Conference on Sustainable Environment and Architecture (SENVAR 2018), Atlantis Press, Feb. 2019, pp. 88–94. doi: 10.2991/senvar-18.2019.14.

[8] O. Acican and I. Dino, “Computational Design Tools and Education: The Smart geometry Case,” Learn X Design Conferences, Jul. 2019, [Online]. Available: https://dl.designresearchsociety.org/learnxdesign/learnxdesign2019/researchpapers/16

[9] A. Ciravoğlu, “Notes on Architectural Education: An Experimental Approach to Design Studio,” Procedia - Social and Behavioral Sciences, vol. 152, pp. 7–12, Oct. 2014, doi: 10.1016/j.sbspro.2014.09.146.

[10] R. Zehner et al., “Optimising studio outcomes: Guidelines for curriculum development from the Australian studio teaching project,” in ConnectED2010–2nd International Conference on Design Education, University of New South Wales, Sydney, June 28th-July 1st, 2010.

[11] S. Roudavski, “Selective Jamming: Digital Architectural Design in Foundation Courses,” International Journal of Architectural Computing, vol. 9, no. 4, pp. 437–461, Dec. 2011, doi: 10.1260/1478-0771.9.4.437.

[12] A. Gönenç Sorguç, “A Computational Design Workshop Experience for 21st Century Architecture Education,” in Sousa, JP, Xavier, JP and Castro Henriques, G (eds.), Architecture in the Age of the 4th Industrial Revolution - Proceedings of the 37th eCAADe and 23rd SIGraDi Conference - Volume 1, University of Porto, Porto, Portugal, 11-13 September 2019, pp. 127-136, CUMINCAD, 2019. Accessed: Feb. 24, 2022. [Online]. Available: http://papers.cumincad.org/cgi-bin/works/paper/ecaadesigradi2019_353

[13] I. Caetano, L. Santos, and A. Leitão, “Computational design in architecture: Defining parametric, generative, and algorithmic design,” Frontiers of Architectural Research, vol. 9, no. 2, pp. 287–300, Jun. 2020, doi: 10.1016/j.foar.2019.12.008.

[14] D. Karadağ and C. Tuker, “A proposal for a computational design and ecology-based approach to architectural design studio,” Int J Technol Des Educ, May 2020, doi: 10.1007/s10798-020-09594-x.

[15] M. McCullough, “20 years of scripted space,” Architectural Design, vol. 76, no. 4, pp. 12–15, 2006, doi: 10.1002/ad.288.

[16] R. Schroeder and W. Dean, “Comprehensive BIM Integration for Architectural Education Using Computational Design Visual Programming Environments,” Building Technology Educator’s Society, vol. 2019, no. 1, Jun. 2019, doi: https://doi.org/10.7275/7gw6-dt36.

[17] A. Agirbas, “A Teaching Methodology for Parametric Design: A Case Study with Parametric Bench,” in SIGraDi 2020 [Proceedings of the 24th Conference of the Iberoamerican Society of Digital Graphics - ISSN: 2318-6968] Online Conference 18 - 20 November 2020, pp. 720-725, CUMINCAD, 2020. Accessed: Feb. 24, 2022. [Online]. Available: http://papers.cumincad.org/cgi-bin/works/paper/sigradi2020_720

[18] P. Belesky, “The Green Grasshopper: Approaches to Teaching Computational Design Methods in Landscape Architecture,” Journal of Digital Landscape Architecture, vol. 3, pp. 406–413, 2018.

[19] S. Soliman, D. Taha, and Z. El Sayad, “Architectural education in the digital age: Computer applications: Between academia and practice,” Alexandria Engineering Journal, vol. 58, no. 2, pp. 809–818, Jun. 2019, doi: 10.1016/j.aej.2019.05.016.

[20] E. Chernyshov, “Light, Dark, and all That’s in Between: Revisiting the Role of Light in Architecture,” Master Thesis, University of Waterloo, 2008. Accessed: Jul. 17, 2023. [Online]. Available: https://uwspace.uwaterloo.ca/handle/10012/3515

[21] Paul Keskeys, “Day and Night: 8 Transformations of Architecture After Dark - Architizer Journal,” Journal, Oct. 14, 2015. https://architizer.com/blog/inspiration/industry/day-and-night/ (accessed Jul. 17, 2023).

[22] Bob Borson, “Natural Light - Clean Aesthetics | Life of an Architect,” Sep. 06, 2016. https://www.lifeofanarchitect.com/natural-light-clean-aesthetics/ (accessed Jul. 17, 2023).

[23] “A journey of Architect Ricardo Legorreta,” The Tiles of India, Jul. 03, 2023. https://www.thetilesofindia.com/global-architects/a-journey-of-architect-ricardo-legorreta/ (accessed Jul. 17, 2023).

[24] S. Piedmont-Palladino, “Tools of the Imagination: Drawing Tools and Technologies from the Eighteenth Century to the Present,” Princeton Architectural Press, 2007.

[25] Syllabus and Middle East University, “Architectural Presentation Syllabus,” 2023. https://meu.edu.jo/pdf/plans/architectureengineering/2020%20presentation%20syllabus.pdf (accessed Oct. 08, 2023).

[26] Future University in Egypt, “Graphic & Visual Skills 2 ARC 232,” 2023. https://www.fue.edu.eg/pdfFiles/Courses/ARC_232_67820.pdf (accessed Oct. 08, 2023).

[27] Mansoura University, “Course Specifications: ARE7123 - Shade and Perspective,” 2023. https://engfac.mans.edu.eg/images/files/engpdf/department/archticture/description/first/term2/Course%20Specifications-ARE%207123.pdf (accessed Oct. 08, 2023).

[28] Holy Angel University, “Graphics 2 Syllabus,” 2023. https://old.hau.edu.ph/intra/courseoutline/pdf/cea-doarc/GRAPHICS2.pdf

[29] T. A. Burnham and J. A. Wong, “Factors influencing successful net promoter score adoption by a nonprofit organization: a case study of the Boy Scouts of America,” Int Rev Public Nonprofit Mark, vol. 15, no. 4, pp. 475–495, Dec. 2018, doi: 10.1007/s12208-018-0210-x.