Key Knowledge Generation

Applications of Technology in Design Disciplines: Perforated Screens and Ornament, the Impact of Digitization in Higher Education

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APPLICATIONS OF TECHNOLOGY IN DESIGN DISCIPLINES: PERFORATED SCREENS AND ORNAMENT, THE IMPACT OF DIGITIZATION IN HIGHER EDUCATION

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Abstract. This research studies the effects and limitations of 3D Modeling/digitization of design on Arab/Islamic screens and traditional designs. The effect of 3D Modelling and simulation software offers unlimited pedagogical experiences for student architects concerning regional and Islam-based perforated screen designs. New Patterns in perforated screens need to be studied. This study highlights the digital production process and how students of ADU relate to digital media in their designs. This research begins with a theoretical framework based on literature review, examines a selection of perforated screens, and allows students to reinterpret them, offering multiple representations of contemporary forms and ornaments of Islamic patterns. This juxtaposition between tradition and modernity is in line with the Abu Dhabi 2030 Vision. It allows academics to breach boundaries between disciplines to examine the effect of 3D Modeling on the design of cultural buildings.

INTRODUCTION

Students in Design studios are currently relying more extensively on digital technology, as means of designing their projects from initial/conceptual stages to final presentation. While these new technologies prepare students as future architects for the industry, they also create a paradigm shift in Higher education especially in design based disciplines such as Architecture and Culture and Heritage studies. This change is mostly visible in the assessment process of design projects as faculty members are challenged to explain to students the importance of design functionality, and regional context versus eclectic forms that can be composed to create spectacular media of representation, that have become of interest to students. Computer-aided design, 3D printing, and computer-aided manufacturing on different scales offer student architects in Gulf States such as the UAE exceptional representation media and three-dimensional design capabilities that are growing hand in hand with rapid urban sprawl in emerging modern Arab Cities such as Dubai and Abu Dhabi. Sandra Piesik outlines today in a rapid era of globalization local craftsmanship are lost in the wake of material changes from traditional materials used in the pre-petroleum era such as coral stone and palm fronts to reinforced concrete, steel, and glass [1].

The scarcity of local vernacular architecture in the Gulf challenges architects to retain regional identity. The remaining examples of Arab adobe courtyard houses stand in contrast with the modern villas. Yet it is essential to study traditional architecture since there has been no gradual transition overtime from tradition to modernity. Today, examples of traditional facades offer an insight for student architects to use a wide variety generated from perforated screens that can be reproduced digitally to fit with modern architectural forms and create the transition from traditional to modern architecture. The new Abu Dhabi Louvre recently opened with it use of a large perforated dome that supports our idea of novelty and importance of reinterpreting local arts and built forms within a contemporary context. The redesign of the Abu Dhabi Central Market represents another example of reinterpreting tradition through its building envelope that abstracts the forms of the Islamic mashrabiya concept on a mega scale [2].

Rendered visualizations of student projects allow them to create complex form, and also to hybridize and morph digital components to create eclectic form that deviates from the authenticity of initial designs in the case of historic monuments and ornaments. Students have become dependent on ready-made digital objects. As faculty mentors, it is essential to guide students to the best practices of using digital technology while retaining their design integrity. This mentorship that is interwoven in the design studios and Computer-aided Design Software (CAD) courses can play a crucial role in enhancing their digital skills and learning experience [3]. The fabrication of ornament is widely appreciated in contemporary Gulf

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architecture and highlights how new technologies reflect similar trends followed by students in order to create spectacular designs. These new technologies are in need of assessment especially in Higher Education as it represents the first step to study the limitations and advantages of digitization of local heritage, Islamic ornaments and perforated screens. Several studies have focused on the effects of digital media on design process, and the ability to create new forms and parametric design. However, limited studies relate the effects of digital media to the fabrication of Islamic perforated screens therefore the objective of this is to highlight digital production process, and how students of ADU relate to digital media in their designs.

LITERATURE REVIEW

The approach of 3D modelling as an educational means to combine theory with a hands on teaching approach proved very effective, especially with the online digital components available to students, that in many cases, are for free and offer new dimensions to the discourse of heritage studies and the production of traditional patterns versus new ornaments and perforated screens. Digital technologies in design allow access to objects from distance, and provoke a re-visitation of conservative modes of instruction and stylistic classification. Digitalization of the design process enables student designers to present their ideas more easily and revisit them several times as corrections can be applied more easily to better understand design context and change/modify elements of design accordingly [4]. In class, it is now possible to digitally revisit many heritage sites and gather much information about Islamic patterns and perforated screens. Digitization of design has also allowed for the creation of morphed forms and an increase in the complexity of architectural design, yet in turn create challenges from the design stage to fabrication [5].

Today, 3D printing machines offer a powerful tool and prepare students for the future, especially the industry. Within the context of studying local heritage in the UAE, digital mediums allow for reintroducing local culture and Islamic architecture and to incorporate the interests of future generations, linking fabrication of Islamic geometrical ornaments to contemporary architecture. Digital heritage allows students to interlace 3D digital skills required by the industry and the instructor's role is to associate them with intellectual analysis of critical issues in the discourse [6].

From a student's perception, digital mediums and 3D printing are highly commended because they provide them with a broad range of case studies and easy production of models that they can modify and recompose to create new forms of design. Digitizing of ornament also allows for modifications of original forms especially scale and proportions. Here the

instructor needs to play an essential role as mentor to help students understand the diversity in cultures of Muslim communities and environmental conditions of production of various forms of perforated screens and ornaments. They can also involve students in research with them highlighting issues such as the impact of Digital technologies on perforated screens in cities such as Masdar in Abu Dhabi, the globalization of Design, and the difference between neo-Islamic design and post modernism. Here learning can be seen primary as a social practice, the teacher and learner should efficiently communicate between themselves through information exchange, knowledge construction and development [3]. Because Dubai and Abu Dhabi have developed rapidly in the past decades, the introduction of digital modelling attracts students' interest in the production of 3D perforated screens as new mediums for the study of local heritage as opposed to conventional pedagogies of learning history [7]. However, students tend to focus on the learning of computer skills rather than theoretical debates and understanding of distinction of stylistic forms, thereby reflecting the interest in the doing part of the project rather than the thinking [8]. The mass of ready-made digital components further complicates the fine differences associated with the production of Islamic ornaments such as building material available, culture, and environmental conditions as the internet offers patterns without their context which can blur the stylistic boundaries for students. Ideally, what is needed for evaluation is pre and post-design theoretical discussion with students to enhance the understanding of culture rather than the tectonics of production. Design outcomes can be measured through the evaluation of structure, learning and understanding, and interest and motivation [8]. Faculty mentorship is essential at this phase since they represent role models for students especially in the design studio. They need to highlight the presence of an influx of forms and fragments of design components and re-orient the structure of the design studio, explaining the pros and cons of postmodernism and challenges of Globalization. Especially that contemporary architecture in the Gulf seeks to offer new interpretations of culture through a regeneration of Islamic ornaments and these new monumental buildings create new paradigms of architectural education that are also meant for retention of an Arab Culture and Islamic urban identity [9]. The new Central Market, the Souq in Abu Dhabi designed by Norman Foster is an example that employs Islamic ornaments to reflect the endless possibilities that are available to designers to create new visions of environmental design that are only possible with today's structural technology and materials. The fabrication of ornament visible on the new Central Market is similar in terms of application to 3D printing since there is no need to rely on the skills of craftsmen. It exemplifies how digital

modelling and prefabrication or 3D printing can be used on a much larger scale of production of ornaments. The new Abu Dhabi Central Market can be viewed as a regional trend to experiment with pre-fabricated pan-Islamic forms and ornaments and has now become part of the living city. Such buildings are appealing to students as representatives of the cultural values of the UAE within the context of modernity and environmental design. It is essential to understand and explain the retrogressive effect of complete reliance on CAD/CAM in architectural practice and education [10], [11]. Challenges associated with digitization of design include a change in relationship between faculty and students and other catalysts of implosion possibly creating an aquarium effect as students are attached to designs from the internet rather than local or regional patterns and ornaments. Here McLuhan argues that it is possible to evolve an obsession with the image of the 'object' than the cultural value of the 'object' itself. Nonetheless, the initiative stimulated discussions on digital derivatives of artistic objects allowing multiple expressions of student's opinions and interpretations [12], [13], [14]. [12] views are shared by [15], who outlines that digital constructs support the creation of simulacra's which according to Baudrillard triggers an indefinite reproduction process resulting in diluting the authenticity of the original object/ornament/pattern [15]. Fabrication of ornament and the decline of the authenticity can be an impact of digitization of design components and their collage if the production process is not closely monitored because with global dissemination, there is an obvious risk of copyright violations in addition to re-defining cultural identities [16], [17].

METHOD AND MATERIALS

In order to test the digitization of ornaments and how it is affected by 3D modelling, a group of students was selected from a class of environmental design and CAD. In both classes, we aimed to study the effect of the digitization on educational approaches to the study of ornaments. The methodology used was observation and ongoing dialogue between faculty member and students that stimulated good classroom discussion. This was followed by student surveys on the design of patterns and Islamic ornaments that they designed using CAD. The study of the digitalized modeling should address the following hypotheses:

- Use of technology adds to the complexity of the reserved knowledge
- Teaching with technology removes the limitations of motivation, pass of information, observation and feedback.
- The impact of the design elements and components is less drastic, which results in losing the sense of the design identity and cultural belonging.

After assuring the aptitude of the students in terms of their competency in using the CAD, the students were asked to use several selected tools from the software in order to create various expressive faade Screen designs, defining different varieties of design styles and methodological approaches. The design was to be produced in 30x30 frame that can be considered as a scale down of the full screen design to fit the required dimensions or a 1:1 part of the screen that can be used as a repetitive pattern in the original faade area that needs to be covered. Students were not limited by particular style or composition. Through this exercise, an examination of the students' perceptions of objects' compositions and the resulting designs and difficulty level of each design consideration of the aid of a digital design tool (CAD) was conducted. Moreover, by maintaining the DWG log file, we could track the students' use of tools, commands, and total time spent on the drawing. After the submission of the assignment, a digitalized online survey created by the use of the same instructor students interaction learning management system, was uploaded for the students to fill. This exercise was conducted on a class that encompasses first and second year students, from Architecture and Interior design majors.

The survey included 28 figurative Questions and a group of 20-23 students participated in the learning experience. Stu dents were asked to define the style of the screens as they categorize it from their own comprehension of the design composition (Islamic, Local, Dynamic, Organic, Conservative, Modern, Geometric, Random/Abstract). And by visually identifying the solid to void ratio of the selected screen, the students were required to interpret the light penetration and privacy level provided. Also, whether they will consider the given deign for an exterior faade design and to rate the difficulty of the design application using the digital aid design tools were examined. After analyzing the information and results retrieved from the survey that was formed and constructed to study the impact of use of digital education and technology in Architecture and design courses, we monitored the students' ability to comprehend cultural and stylistic differences between traditional patterns and ornaments.

The first step conducted in the Architecture and Environment course was a digital reconstruction of the historic house of Sheikh Maktoum bin Hasher al-Maktoum (the founder of Dubai) that was given to students. The aim was to get students to understand through learning by doing how traditional vernacular architecture in the UAE addressed space planning of a traditional courtyard house, evolution of design that is climatically responsive, and manifests the limited local building materials available in the region at the time. The project also helped students understand the complexity of constructing digitally a local wind tower (barjeel). The digital reconstruction

of Sheikh Saeed's house also allowed for examination of local patterns of perforated screens and the solid to void ratios of the facades (Figure 1). Detailed plans for the model were drawn using CAD programs including sections and elevations. Plans and sections were provided to students from the Dubai Heritage section in Dubai Municipality. These plans and sections showed the condition of the house before and after restoration.
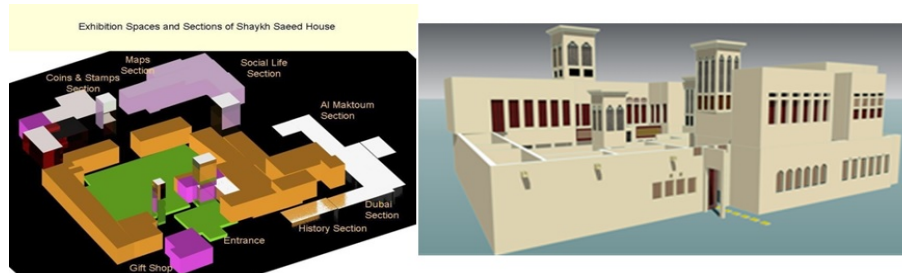

Fig. 1. Sheikh Saeed House (Dubai) digital reconstruction by students

The Sheikh Saeed 3D reconstruction was conducted over a one-semester timeframe, and was part of a larger project to create three-dimensional computer models for traditional ornaments, especially perforated screens. Two software programs were used; the first AutoCAD for 2 dimensional drawings, i.e., plans and elevations; then Sketch-up to create the three-dimensional components of the perforated screens (Figure 2) that were later exported to the laser cutting machine or 3D printer based on the preference of the students to the production process and medium.

The exchange of ideas related to the production of 3D perforated screens adopted from local heritage allowed students to actively participate in a dynamic and integrative environment, enabling manipulation of solids and voids, application of textures, lighting, and color schemes. Digitalization of the components and ornaments of Sheikh Saeed's house offered new insight to the study of local Heritage in Dubai and the UAE, as students were able to easily acquire images and texts, create 3D models, then explore the pros and challenges of the media of ornament production.
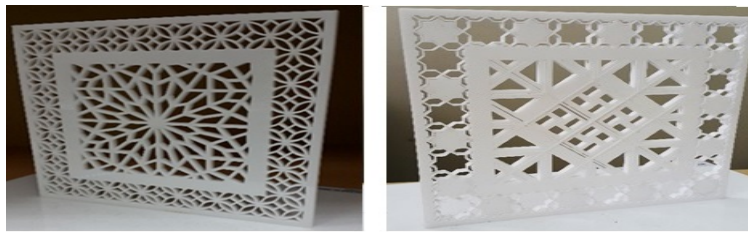

Fig. 2. Islamic inspired perforated screens fabricated by laser cutting

Ornament Fabrication and Contemporary Design

Contemporary architecture in the Gulf reflects on this notion of universality/globalization as arts and crafts of Islam display a broad spectrum of cultural production from Mughal India to North Africa and Spain. The Emirates Palace, Sheikh Zayed Grand Mosque, Masdar, and new Abu Dhabi Louvre, all display carved Screens, tile work marble inlay, and arches rendered in GRC, stone, stucco, and wood blurring the boundaries of initial centers of production of ornaments because historically, craftsmanship and materials differed from one region to another reflecting cultural context and diversity in communal values. The pedagogical approach used to explain the new forms of

Islamic architecture emerging in the UAE was through physical modelling, which allowed us to combine theory with a hands-on practice. Students were first introduced to the basic definitions of sustainability. They learned through theoretical conduct the different views of sustainability, what it is, and how it can be delivered. The negative impact of the building and construction industry on the environment came as the main drive to captivate students' attention and improve their skills. Significant percentage of energy resources is consumed by residential architecture. Therefore, as an assignment, students were requested to fabricate perforated screens as part of their learning experience and application of different designs. Students were guided

throughout the course of the semester to not only think about the current needs of people, but also to put the industry needs and market competition in their minds. A hands-on approach to designing screens was used which proved to be a popular technique that helped the students understand the importance of sustainable design and passive cooling and allowed them to implement sustainable design concepts they had recently learned and put their newly born sustainable awareness to action. This could be achieved without contradicting with the main design and concept creation phase, as they can actually use it to add individuality and pioneer to their designs and forms. Each group was required to come up with 3 to 4 different innovative Screen designs that can be constructed and implemented in the United Arab Emirates precisely and the Middle East region generally. The aim of the screen design was to provide privacy for the conservative inhabitants and grant the building with an exclusive unique design, which extinguishes the building faades and grant the form with particular conceptual approach and cultural trace. They were required to model the screens physically in 30cm x 30cm, either by scaling down the full screen design to fit the required dimension or scaling part of the screen that can be used as a repetitive pattern in the original faade area that needs to be covered. The groups started with sketching and brainstorming concepts and ideas to produce screens that reflect particular design approaches and trends. Variety of concepts were covered. Some screens were based on the traditional patterns and embod-

ied designs of the Region as they were aiming for reproducing traditional patterns, (Figure 3) while another group decided on introducing contemporary and abstract designs that they believed would fit better with the rapid rate of urbanization in Abu Dhabi and the UAE. Two main criteria were given to students, the first being Privacy and the second was the effectiveness in protection from Direct Sunlight. For evaluating the privacy level of the screens, a void to solid ratio was quantified by valuing the ratio of the sum of the areas of the window/screen openings to the gross area of the window/screen with an approximate ratio 1 to 0.7, i.e., the larger area of the screen was actually Void, providing more exposure to the interior spaces. The privacy level was increased by proposing to cover the openings in the screen with a translucent material, such as fiber glass, to allow the sunlight in without exposing the interior of the building. For the second criterion, i.e., the protection from direct sunlight and glare, students had to study the direct sun reflection level of the screens by creating a 30 x 30 x 30 cm testing box that was open from one side and had a small opening on the opposite side for measuring the light intensity and effectiveness of the screen. Students took their inspiration from design abstract shapes that they abstracted and applied irregularly in a random distribution. They discussed as a team how geometric shapes could add an edge and character to a modern building and how it affected its volume and form.
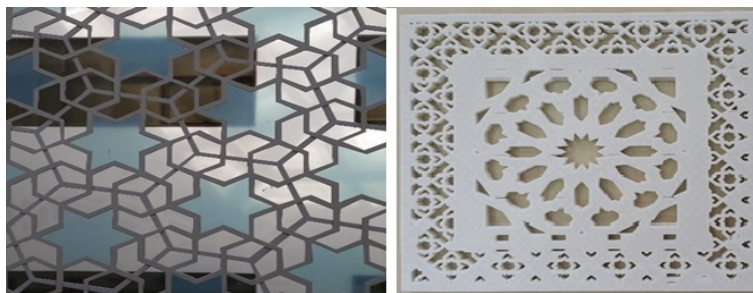

Fig. 3. Islamic inspired perforated screens fabricated manually and by 3D printing

In another attempt, students opted for an Islamic interlacing star pattern and tried to apply it within a modern context. Students used combinations of repeated squares, circles, and polygons, and tried to interlace and overlap to create complex patterns. They came up with repetitive patterns and singular large less clustered motifs. They felt the need of reflecting the culture and tradition of the region through the building faade regardless the building function. The aesthetic feeling that occurs from the shadow casted on the interior developed a cultural identity to the space and students felt that it created a good counter

design in an era of globalization. Through screen design, students were introduced to a better understanding of sun shading devices and louvers and, however, they functioned technically through the design of their basic elements. In the context of modern architecture, louvers are not known for being a fundamental design elements. They also understood the complexity of combining aesthetic and cultural criteria with a technical device. This incited students to innovate and work as a team to discuss designs that embraced aesthetic as well as technical qualities. Adding the privacy component is an essential element

in the design of Emirati dwellings and community that highly values privacy. The range of effects in Islamic architecture achieved through the variation of light screens is extraordinary [18]. This is especially seen in Masdar and the new central Market designed by Norman Foster (Figure 4). Mashrabiyya screens developed overtime to the rules of geometry, that created patterns organized according to rectilinear or radial grids, in which a circle and its polygonal and star shaped derivatives play a prominent role [19]. Owen Jones in his seminal work the grammar of ornament [20] discusses in great detail how geometrical principles have created smooth transitions from curve to curve, and how vegetal designs created a certain flow of ornaments from a parent stem to floral motifs and various

subdivisions. [20] addressed issues such as square decorations that were designed to produce repose, the lines whether straight or inclined, and the lines running horizontally, perpendicularly, and diagonally to give contrasting effects [20]. Islamic ornament was the focus of Oleg Grabar' [21] in his book Formation of Islamic Art, in which he tried to use the example of Islamic ornament to meditate on larger issues of the perception, utilization, and fabrication of visual forms. Grabar also addressed the materiality of ornament highlighting that Stucco, then, was a technique of surface decoration that transformed a building cheaply and flexibly as opposed to mosaics, stone carving and wooden inlay that required more complex technical preparation [21].

Fig. 4. Islamic inspired perforated screens in the new Central Market of Abu Dhabi
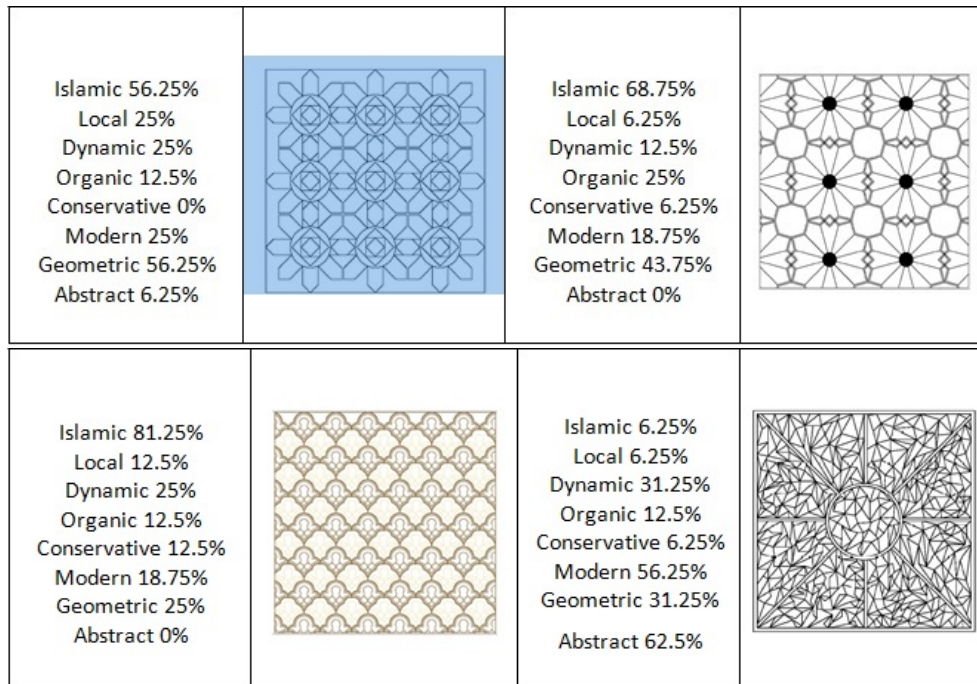
RESULTS AND LIMITATIONS

The study of digitizing of ornament has shown that students value heritage in multiple ways. Therefore, Faculty as mentors can help students to explain the various forms of production and appreciation of ornaments. They can also involve students in research with them and, during this process, address issues such as the impact of Digital technologies and the globalization of Design. Here learning can be seen primary as a social practice. The teacher and learner should efficiently communicate between themselves through information exchange, knowledge construction, and development [3].

Students showed great interest in the production of 3D modelled screen designs because of the use of technology which represented a new medium for them, regardless of the challenges between conventional pedagogies and a modern teaching environment that was facilitated by new digital technologies [7]. 3D printing also helped explain the complexity of production/manufacturing of jail screens since some parts remained solid and screens below a certain thickness. And their appreciation of explaining complex technical issues through a hands-on approach and learning through implementation. However, digital

technology is not expected to completely reduce the importance of student/faculty interaction. Rather, it can enhance and simplify some of the complex operations that were associated with conventional education environments. In the process, some challenges and problems were encountered during the 3D digitalization. The students noted that more complicated and perforated the design the thicker the material should be to maintain its strength. When using the Laser printer Poly (methyl methacrylate) or Acrylic glass with a thickness of 3 mm was used to give more strength and stability for the design, and avoid heat bubbling and edge burning. The printing took from 15 to 20 minutes according to the intensity of the design and the product was instantly ready to be handled. The students had to communicate the solid/void process with the digital design software before proceeding to the 3D printing to identify the perforation in the screen design. During the experience of producing Islamic ornaments within a digital environment and creating 3D printed models, we observed that the learning environment encouraged the students to try complicated and provocative designs without worrying about the do-ability of the manufacturing knowhow. This extended the limits of design

possibilities due to the availability of laser cutting machines and 3D printing facilities. Digital technology offers the Instructor new venues of experimentation with ornaments and design more

complex patterns that would not have been possible to produce manually. It also motivated students to produce a diverse range of designs in a short timeframe (Figure 3).

Islamic 56.25%
Local 25%
Dynamic 25%
Organic 12.5%
Conservative 0%
Modern 25%
Geometric 56.25%
Abstract 6.25%

Islamic 68.75%
Local 6.25%
Dynamic 12.5%
Organic 25%
Conservative 6.25%
Modern 18.75%
Geometric 43.75%
Abstract 0%

Islamic 81.25%
Local 12.5%
Dynamic 25%
Organic 12.5%
Conservative 12.5%
Modern 18.75%
Geometric 25%
Abstract 0%

Islamic 6.25%
Local 6.25%
Dynamic 31.25%
Organic 12.5%
Conservative 6.25%
Modern 56.25%
Geometric 31.25%
Abstract 62.5%

DISCUSSION

Islamic Ornaments that can revive traditional forms and allow their application on high-end steel and glass iconic buildings, creating a linkage with local context and environment. Digital technology, in relation to the manufacturing of ornaments, is still in its infancy phase. However, it has proven quintessential to the process of student learning, regardless of discussions related to a cultural clash between conventional pedagogies and the digitization of design and ornament. As outlined by [22] modern teaching pedagogies facilitated by new digital technologies and model-making play a crucial part in the early stages of architectural design. It captures spatial

perceptions and allows for three-dimensional thinking to be visualized by students, hence establishing a direct connection between the designer and the object through three-dimensional models [22]. Digital technologies offer new opportunities for student architects to picture, connect and make assumptions related to the manufacturing process. Students showed a better understanding complex technical issues through a hands-on approach and learning through implementation, especially that they could produce a variety of star patterns that were ideally suited to computer-controlled manufacturing [23]. In our research, we approached the study of traditional forms from a

hands-on perspective that hinges on alternative and interpretive freedom offered to students to produce interesting design forms that have linkages to Arab/Islamic references. Digital technologies in design available to us today allowed our students to establish an initial understanding of the phenomena of using traditional forms while retaining a knowledge of their reference and origins. This study allowed us to highlight to students that thinking through the computer is not the same as producing a perforated screen/mashrabiya/Jali by hand which in the process also allows for modifications and development of talented teams of craftsmen. During this experiment, we attempted to address the issue of materiality and means of production by using Islamic patterns. It was noted that a variety of star patterns can be rendered via a variety of methods and materials, which allowed students to discuss as a team how geometric shapes could add an edge and character to a modern building and how it affected its volume and form. The experience has also allowed student architects to construct new portrayals of ornaments and test their designs on-the-spot through Digital modeling, 3D printing, and laser cutting. Involving students in the survey and creation of digital 3D models for selected buildings allowed students to participate in offering solutions to improved designs and assessment of precedents. Students learned to highlight the intrinsic values between cultural significance and designing

architectural icons.

CONCLUSION AND RECOMMENDATIONS

This research assessed local heritage in order to increase the critical consciousness about ornament and Arabian identity. Our main research finding addressed assessment of interpretations of tradition, and will be addressed through literature review, field surveys, and comprehensive documentation of selected buildings and an assessment of regionalism versus institutionalization administered by global architecture. Students better understood the correlation between modern heritage studies that are heavily founded on literary review and theoretical discourses which are difficult for student architects to translate to actual design practices. Digital technologies and 3D printing allowed us to intertwine design with historical theory applied to architecture with a focus on heritage. In this study we highlighted the cultural values of the UAE within the context of sustainability and environmental design proved to be effective since students showed great interest in their production of several screen designs. And their appreciation of explaining complex technical issues through a hands-on approach and learning through implementation. The use of the contemporary geometries reinterpreting traditional patterns on screens represents an inevitable necessity in the creation of a building's identity in the modern Arab city, to counter global changes in architecture.

Declaration of Conflicting Interests

No conflicts of interest.

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