Silk Road: A Reference. Creating public architectural intervention in the context of education & technology.

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Abstract: Silk Road is a public architectural installation that was created in a university fabrication lab and then shipped and assembled on-site. It is made of wood and metal fasteners using original CAD files and a digitally driven CNC machine. Its form references key moments in Islamic architecture by combining three shape specific profiles from structures found along the silk road. The three shapes are combined together to create a new presentation of architecture using the ancient forms as the design catalyst. Three design students, two Jordanian and one Egyptian, along with their American architecture professor acting as project mentor designed and built the full-scale project in a period of 3 months. In its physical form, the project is an art pavilion placed in the public domain inviting the public to speculate and consider both the cultural references of the architecture as well as the tectonic fabrication.

Keywords: Technology, Design, Education, STEM, Architecture

1. Introduction

1.1 Project Background

The goal of this project was to identify and facilitate applied research within the discipline of architecture associated with prototyping technology and STEM learning methods with a real world project as a platform for moving between scales of small, medium and large prototypes before final fabrication and construction. It is also concerned with how this process can contribute to the education or curriculum for design education. In a recent article in the Seattle Daily Journal of Commerce, (Mansavage), there is a current movement in the technology fields to incorporate more creative & critical thinking which can alter the acronym from STEM to STEAM, placing “art” and creativity into the mainstream STEM disciplines. This makes perfect sense for architects given the fact that the discipline is taught using concepts of science, technology, engineering and math from a decidedly creative perspective whereby materials, compositions, arrangements and an artistic design logic of tectonic and stereotomic manifestations is an everpresent component in the conversation of design education.
Although making through technology is not the only aim, the project sought a high engagement in technology so that potential results could be directly influenced by on-going critical decision making via rapid prototyping, numerical tolerances and evaluation processes through trial and error. This created a more competitive full-scale project in the end and the ability to work through details of full-scale fabrication and construction with more confidence. Equal parts architecture, digital workflow, fabrication, this project covered an in-depth process of research for fabrication relative to teaching in the design profession, along with an uncovering of the potential STEM processes design students can use to move their work to a higher level of efficiency, critique, practice & craft.

1.2 Background Questions

This project employed the process of making as a way to question the role of architectural education techniques and the role of design practice in contemporary climate. The use of technology is commonly used in both design education and practice in the form of Computer Aided Design (CAD) and an expansive host of subsequent tools that can be controlled by this software such as laser-cutters, 3D printers and CNC machines. Moving further, the tools have explicit implications on choices made for final design based upon material. In the article, “Keswa”, when discussing a similar process in the context of education, the architect Emily Baker references prototyping in digital fabrication as “being not only about “cut patterns” of material but something that “produces a specific effect in the material and allows students to develop a haptic awareness of the material and understand its reaction to their digital processes.” She continues the discussion by saying, “In all acts of constructing, but particularly within digital fabrication processes, not only the properties of the material, but also the properties that emerge in the pairing of a material with a specific tool or process, become the milieu for the designer.”

This sets up an interesting conversation on the differences of “size” vs “scale”. However, with the vast ecology of technological vehicles, it is sometimes difficult to ascertain what the actual values are for a specific project, and whether or not technology is the driver of the project, or rather used to leverage an outcome along the way. It was important in the context of this project to understand how technology and education come together and how students and professors employ this intersection for production and making.

Whereas some modes of design education privilege that act of drawing over making, this project and its related outcomes aligned CAD modeling with “student making”, “scale vs size analysis”, and “tool efficiency” relative to material choice to create a full-scale physical example of architecture that in doing so, considers 3 fundamental questions of contemporary STEM teaching in design:

1. How do we as students/professors use tools for learning?
2. How do we as students/professors use tools to inform design?
3. How do we as students/professors use tools to produce design?
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Figure 1: Image depicts a CNC in the university lab cutting pieces for the Silk Road Project.
2. Venue & Context for Research

In the Fall of 2015, three design students and a professor of architecture began discussing ideas regarding a recent competition announcement that would facilitate the funding for a full-scale architectural project in the form of a pavilion. The project needed a strong cultural identity, as well as a persuasive final design presence. Because the winning team would be required to build the design, it also needed a convincing sense of understanding relative to full-scale manufacturing and construction within a given budget and time-frame.

The project used the national competition as a vehicle for placing studio research into a real world context & scenario. The team felt that through this competitive mindset, professors and students have a chance to work together in advancing mutual pedagogical dialogue, but also to create an ongoing record of heritage and culture for a region that has not had a consistent history of documented arts projects. The competition proposal had design intents that created a large scale architectural work that met the following criteria:

4. The project can be publicly exhibited
5. The project can create cultural impact on local public space
6. The project can advance the local understanding of producing art & architecture in the region
7. The project can improve local understandings of using STEM activities between students and professors

As a result of this process, the project team, all majoring in architecture, created a 16 meter long contemporary art pavilion that celebrated the heritage of the history of art and architecture found along the silk road. The project was later reduced to 8 meters to fall in line with project cost and lead times.

To reflect a strong sense of cultural context the project referenced the Isfahan, the Mamluk, the Andalusian, and the Umayyad Arch, four common arches found in Islamic architecture along the Silk Road.

The project venue encouraged the team to think critically and creatively about how to build, exhibit, ship, and orally defend the work. The design, prototyping, and final construction of the project was executed with multi-axis X,Y,Z Computer Numerical Controlled (CNC) routers that required mathematical calibration on a daily basis whereby tolerances were managed down to 0.5 mm. and material efficiencies were optimized to increase sustainability & reduce significant portions of waste. Part of the learning process allowed professor and students to present the design concepts to a panel of international judges and to a private team of international marketing and business consultants. The oral component of the process allowed the professor and students to work together very closely and develop professional team dynamic. It also allowed for very straightforward cross-pollination when creating line-item budgets for construction and understanding material lead-times with a project that needed to be completed within 3 months.

3. Conceptual Approach & Design

The conceptual approach for the design of the pavilion takes inspiration from Islamic art and architecture. One of the challenges to this was that the use of Islamic influences spreads across many different countries and time periods, some of which used the shapes within the framework of their own unique cultural building method making it hard to distinguish the purity of a form.

Ultimately, it was important for the design team to research and locate commonalities among this vast lexicon of design examples. Over the course of several weeks the team was able to locate 4 very common arches that are found in a vast array of Islamic examples. These were the Isfahan, the Mamluk,
the Andalusian, and the Umayyad Arch. These arch profiles can be found in temples, mosques and houses throughout the many regions of the Silk Road.

For centuries, the Silk Road journeys linked the Islamic culture to trade, prosperity, danger & safety. This culture prized architecture, and the architecture played a key role in facilitating the infrastructure of the route and it also created key buildings for trade. Additionally, the continued presence of people created a need for a further hosting of architectural needs, primarily for worship, and shelter. These were the buildings that welcomed people home from dangerous journeys and allowed them comfort on the road.

The history of the Silk Road has many pages, but most consider the Silk Road to be the trade route that linked Chinese, Arab, and European civilizations. The Persian Royal Road which acted as one of the primary arteries of the trading route connected modern day Iran, Turkey, the Indian subcontinent, Mesopotamia, and Egypt. Eventually, this would influence architecture from China, to Persia, to Spain.

The expansion of trade allowed for the influences of this architecture to move even further. The project uses these influences as a design catalyst for architectural shape explorations and form generation.

At one end of the pavilion, the form begins with the Umayyad Arch from Damascus. Umayyad architecture developed in between 661 and 750, primarily in its heartlands of Syria and Palestine. It drew extensively on the architecture of the defeated Byzantine empire, but introduced innovations in decoration and new types of building such as mosques with mihrab’s and minarets.

The form of the pavilion then moves to the pointed Safavid Arch which was used during the Isfahan Era. Safavid art is the art of the Persian Safavid dynasty from 1501 to 1722. It was a high point for the art of the book and architecture; and also including ceramics, metal, glass, and gardens. The Safavid Empire was one of the most significant ruling dynasties of Iran. They ruled one of the greatest Persian empires, with artistic accomplishments, since the Muslim conquest of Persia.

As the pavilion moved inward, the central arch is a representation of a more curved arch from the Mamluk dynasty. The architectural legacy of the dynasty includes the Qutb Minar and the Mausoleum of Prince Nasiru’d-Din Mahmud.

The final profile is taken from the Moorish architecture of the Andalusian period. Characteristic elements of Moorish architecture include muqarnas, horseshoe arches, voussoirs, domes, crenellated arches and lancet arches. The Moorish architectural tradition is exemplified by great buildings such as the Mezquita in Córdoba.

The arches are built over a central pathway that symbolizes the silk road, the ancient trade route upon which all of these empires were formed. These ancient shapes are the same ones that once welcomed traders home from the Silk Road and allowed them shelter on the road. Inside, the form is lined with intricately printed fabric which acts as a translation to the core trade of textiles throughout the deserts and sand dunes of the Arabian Peninsula. The artwork acts as an homage to historical architectural forms, a reminder of the perils that this region has faced, and the resultant beauty that helped define the culture, a constant timeline of “leaving” and “returning” home.
Figure 2: Isfahan Arch. The Umayyad mosque at Damascus. Illustration of a tale. Page from a manuscript known as Kitab al-bulhan or “Book of Wonders” held at the Bodleian Library. Shelfmark: MS. Bodl. Or. 133
Figure 3: Umayyad Arch. Shah Mosque. Painting by the French architect, Pascal Coste, visiting Persia in 1841.
Figure 4: The Mamluk Arch. The Khanqah of Sultan Faraj ibn Barquq.
Figure 5: The Andalusian Arch. A general view of the interior of the Mosque at Cordova – from the book "Arabian Antiquities of Spain" by Murphy, James Cavanah, 1760-1814, published in 1816.
The project was designed in 2 specific phases, the first of which was orally presented in a public venue with a panel of judges. The original proposal had a 115 individual arch profiles with a maximum height of 4.5 meters (14 feet 6 inches) and a length of 16 meters (52 feet 6 inches). The project was awarded first place in the competition provided that the design team was able to reduce the size of the pavilion in order to align with the jury’s decisions of what the final size should be relative to funding and time. With this in mind, the team then re-designed and presented a new proposal with 65 individual arch profiles and a maximum height of 2.9 meters (9 feet 6 inches), and a length of 8 meters (26 feet) all made from baltic birch plywood and manufactured with CNC technology from original CAD files that reflected the common arches used in Islamic architecture found along the silk road.

4. Methods of Testing & Production

4.1 Methods & Approach: CAD/CAM

The approaches used in this project are not unique to architecture. They are commonly used in the fields of Industrial Design, Studio Art, Furniture Design, Digital Fabrication and Architecture. Because they are so widely used, they have a fundamental impact on design education. Architecture, for years, has been subject to the know-how of the contractor in the field, and the know what of the architect in the office. The technology employed in this project allows the architect, and the architecture student, to become a more committed craftsman by using their design skills to design and test. It gives them the direct ability to experiment with material, and divine a solution based on craft and aesthetic rather remain subservient to outsourcing.
As a result the methods begin to evaluate the quality of work relative to material decisions, detail decisions, and decisions with connections.

One of the students in the design team offered the following quote as related to the methodology, “There are various tools at our disposal as students. The involvement of these tools depends on various aspects including the design and the expected outcomes of the design project. With this project, we were aware about the possibility that the project would be built, thus we had to involve more tools in order to realise the design we came up with. In a studio project in comparison, a physical model presents a challenge because we heavily depend on digital tools to realise the design project.”

This project and its related outcomes aligned CAD modeling with “student making”, “scale vs size analysis”, and “tool efficiency”. The final pavilion is made of 64 individual wooden layers. Each layer varies in shape and size due to the specific curvature of the independent shape profiles. Ultimately the profiles complete a form that reflects ancient architectural patterns, but individually the shape contours are abstract parts to a whole. The project team solved problems of connecting the large arches together by experimenting with CNC cut scarf-joints. The process created several failures before finally allowing the team to connect the fabricated wooden pieces together in an aesthetic way that was acceptable to the design goal.

![Figure 7: Original Image from project presentation depicting a stacking of individual arch pieces in the fabrication lab. Each piece is a morphosis from a traditional Islamic arch.](image)

The methods represent significant student learning outcomes in which a student post-learning evaluation was done. When asked about the specific learning criteria of the project, the student said, "Being aware of the tools at our disposal helps direct and develop a certain attitude that aims to involve all these tools and to fully realise their potential. The more I depend on digital tools for instance, the
more complex and conceptual the design becomes. Involving other tools such as those in the labs would change that attitude and would result in a process that focuses more on physically realising a design and account for more factors which consider the tools limitations.”

This project employed the use of the computer aided design program “Rhinoceros” by students and professor as a communication tool for design and output. It is a free form surface modeller that utilizes Non Uniform Rational B Splines (NURBS) to generate mathematical models of physical shapes. Rhinoceros allowed the project team to move quickly between scales, make corrections on overall form and adjust the tolerances of fabrication & construction. It allowed the team to output to laser-cutting machines, 3D printing machines, and CNC machines.

**METHOD 2: SMALL SCALE-LASER**

The project required students take on design work in a very critical day to day environment and also that it be buildable, functional and safely installed within a given timeframe of three months. Laser cutting technology allowed the project team to create and manufacture a physical prototype daily, which subsequently informed the final design. It allowed the team to work closely with material thickness and assemblage using a single sheet of material that fits into a standard laser cutter bed of 18”x32”. This encouraged design thinking where joinery and connections needed to be explored and made from within the material, as well as evaluating connection points between modules and structural ability. It also created an environment where the project was to be built out of flat material. As a result, material efficiency was an innate characteristic of each and every cut file that the laser produced, and this had subsequent influence over the large scale fabrication with the CNC. The laser is capable of cutting materials with extreme tolerances, often to within 0.001 inch (0.025 mm). As a result of this process, the team incorporated a more direct logic when planning and augmenting the design process and transfer of data during the facilitation of construction.

**METHOD 3: LARGE SCALE-CNC**

Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) are the primary catalysts relative to technology that have facilitated great change in design education. A subsequent conversation in design school is taking place regarding the architect’s capability to regain control over the process of building and become again the “master-builder”. Rather than only drafting projects and outsourcing the drawings to a builder, this allows designers to design, critically evaluate, and build versions of their own projects more efficiently. Through the use of CNC manufacturing hardware such as routers, mills and a milieu of various cutting machines, “mass customization” is overcoming the pit falls of ‘mass production’. In this project, students and professor utilized large scale CNC machines to prefabricate a large architectural pavilion in three separate pieces that could be trucked to the site and pieced together by workers that had no prior experience. During the process of fabrication, students and professor created many of their own structural components and were able to critique function and craft in the same conversation.

Relative to production, a student form the design team made the following comment upon the question of the use of tools in the design process, “Using the tools in the labs presented a challenge since we weren’t fully aware of their limitations during the design stage. Having not received the necessary training to use the CNC router for example has hindered my ability to propose solutions to the problems we faced during the production phase. There is a greater focus on digital production than physical production, thus we don’t get to fully realise our designs due to the lack of awareness of the capabilities of the tools we have. We don’t use enough tools I believe.”

**5. Conclusion**

This is a project developed in an experimental pedagogical context. It is specific to an architectural agenda but lends itself as a model for professions of Industrial Design, Furniture Making, and Studio Art. Irrespective of disciplinary background, design students can benefit from the outcomes of working with
tools at a 1:1 scale. Based upon the outcomes of this project, it is of primary importance for students to understand that there is a fundamental difference between concepts of “scale” vs concepts of “size”, and that this difference relative to the use of tools in the design process can be a seminal moment in understanding the limit/potential of material and final project.

In a recent paper “Algorithmic Futures, the Analog Beginnings of Advanced Parametric Design in First Year Studios” the author Patrick Rhodes discusses student making, computational design and ideas of craft & materiality by using Mario Carpo’s references to the artist Sol LeWitt. In this particular context the author describes the notion of indeterminacy when using computational tools as a strange one, where he finds himself between two groups, the phenomenologists on one hand and parametric designers on the other, and contends that both are concerned with the indeterminate, and the search for mystery in the process. But to try to find it in computation, he argues, is irrational. But it is this irrational thinking tempered by rational, logical execution that LeWitt believes leads to new experience and gives art and design its vitality (LeWitt, 1969).

In design pedagogy, many times scale and size co-exist as factors that effect the decision making process impacting both the digital and physical outcome of a given project. However, if this process is not elaborated on during the design phase of a project with robust iterations of 1:1 material experimentation as an integrated factor in our intellectual process, we run the risk of not moving beyond the oral critique relative to physical material realities and how these realities affect the overall stereotomic or tectonic versions of the design. Tools must be employed to become part of the decision making process so that such intellectual investments create more accurate decision making as it relates to material, actual detailing, cost, and assemblage. Understanding how projects are put together in the field and shipped to a job site have impacts on everything from sustainability of resources, to labor, to finished craft.

The current profession of architecture is ever-changing and evolves around new technologies, trends, social systems and cultural developments. What has driven the profession for centuries (locale, proportion, divinity, order) has currently taken a different role in the design process and has been substituted in many cases by explorations in the fields of material and computer science combined with a revolution in digital fabrication/design and the exposure to a wider cross-section of STEM for design professors and students. With this comes a need for continued and further experimentation with physical craft and the actual process of making, but also presents a need for further development in design curriculum whereby STEM, or “STEAM” concepts are employed to assist and evaluate potentials for a given design process or outcome. For the project “Silk Road”, the research presented an enlightened speculation into the potential for using tools for teaching new methods of practice and subsequent craft that architects are/will soon employ as the parameters of the design/materiality/process relationships expand.
Figure 8: Original Image from project presentation & CAD file depicting the arches modelled together in space. The arches form the final shape of the pavilion.

Figure 9: Original Image from project presentation & CAD file depicting the arches stacked in fabrication lab.
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Figure 10: Original Image from completed project.
Figure 10: Original Image from completed project.
Figure 11: Original Image from fabrication.
Figure 11: Original Image from process drawings.
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Additional References:

Certain information for images has been taken from a manuscript known as Kitab al-bulhan or "Book of Wonders" held at the Bodelian Library. Shelfmark: MS. Bodl. Or. 133.