# Otavalo Textile Grammar: Patterns and Dialogues

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**Abstract.** This paper focuses on the woven textiles of Otavalo, Ecuador, as a case study for improved cultural representation in architectural design. A shape grammar methodology is used to identify specific geometry and elucidate relationship rules found in existing artifacts. These geometry and relationships are subsequently used to produce patterns; both replicas of traditional tapestries as well as new configurations. Extending from 2D to 3D and from digital to physical, sets of modular prototypes are developed based on patterns produced using the defined Otavalo Textile Grammar. Model parts are supplied to study participants; new building blocks for architecture as a spatial and social undertaking.

**Keywords:** Maker culture, Design computation, Shape grammars, Digital craft

## 1 Introduction

This research views architecture as a language capable of transcending linguistics boundaries and creating cultural dialogues. In accord with the writings of scholar and activist Gloria Anzaldua, we concur that much of the built environment is monocultural; “lumped together, our issues collapsed, our differences erased.” (Anzaldua, 1987) Rather than neutral articulation, true multicultural space must, Anzaldua continues, “[include] stories of difference.” Unfortunately, such architectural expression and programmatic goals are not always incorporated into building design.

One area where cultural expression can be observed – and thereby serve as architectural inspiration – is textiles. We find numerous examples throughout the world, each unique to their place and people – embroidered and mirror-embedded Shisha fabric of India, vibrant wax-print Ankara cloth popular across Africa, and intricate cross-stitch designs from Hmong, Vietnam – to name just a few. (Postrel, 2020) Often still created today by artisans using methods dating back hundreds of years, these textiles clearly consider issues familiar to architecture; materiality, process, and pattern. But further than that, these acts of creating a) preserve cultural traditions, b) articulate ethnic identities, and c) strengthen community connections. In other words, the making of textiles is synonymous with creating spaces for sharing stories of difference.

This research focuses on the woven textiles of Otavalo, Ecuador, as a case study. A shape grammar methodology is used to identify specific geometry and elucidate relationship rules found in existing textile artifacts. These geometry and relationships are subsequently used to produce patterns; both replicas of traditional tapestries as well as new configurations. The Ecuadorian custom of weaving is centuries old. Portrayed in Figure 1, yarn is spun from alpaca wool and woven on treadle looms to produce blankets, cloths, bags, and more, for sale at the famed Otavalo market. (Rowe et al, 2007) Similar studies have used shape grammars to disclose the organizational language of other culturally significant work, including, for example, Chinese ice-ray lattices (Stiny, 1977), Mughal Garden designs (Stiny and Mitchell, 1980), and wire-bending for costumes in the Trinidad Carnival (Noel, 2015).

Extending from 2D to 3D and from digital to physical, sets of modular prototypes are developed based on patterns produced using the defined Otavalo Textile Grammar. Details of these models are specifically designed to allow assembly in a variety of ways. Model parts are supplied to study participants for experimentation. Participants are also provided a series of prompts and survey questions, responses to which inform further model iterations. The assembly of these scaled architectural models – like making of the inspiring textiles themselves – encourages dialogue among participants on topics such as differences in culture, techniques of making, and inclusion.


**Figure 1.** Making (left, from April, 2020) and marketing (right, from Ucros, 2015) Otavalo textiles.

## 2 The Otavalo Textile Grammar

### 2.1 Otavalo textiles

Otavalo textiles may be categorized into three generalized pattern types as illustrated in Figure 2; axial, banded, and field. Axial textiles are often radial and display strong symmetry. Banded textiles are organized in stripes of various widths and designs. Fields are created through repetitive tiling of one or more geometric shapes. These pattern types can also be combined; axial patterns are often flanked by bands and have repeating elements, striped patterns can be organized symmetrically and incorporate radial configurations, tessellations are formed by regular figures and have an underlying logical structure.

Whether used to create geometrical patterns or figures such as mountains, plants, or animals, it is observed that many Otavalo textiles incorporate the same shape time and again: the *isosceles trapezoid.* A member of the quadrilateral family of shapes, the isosceles trapezoid is characterized by two parallel sides (making it a trapezoid) and symmetry (classifying it isosceles). Figure 3 demonstrates the recreation of a typical Otavalo textile using various sized and configured isosceles trapezoids.

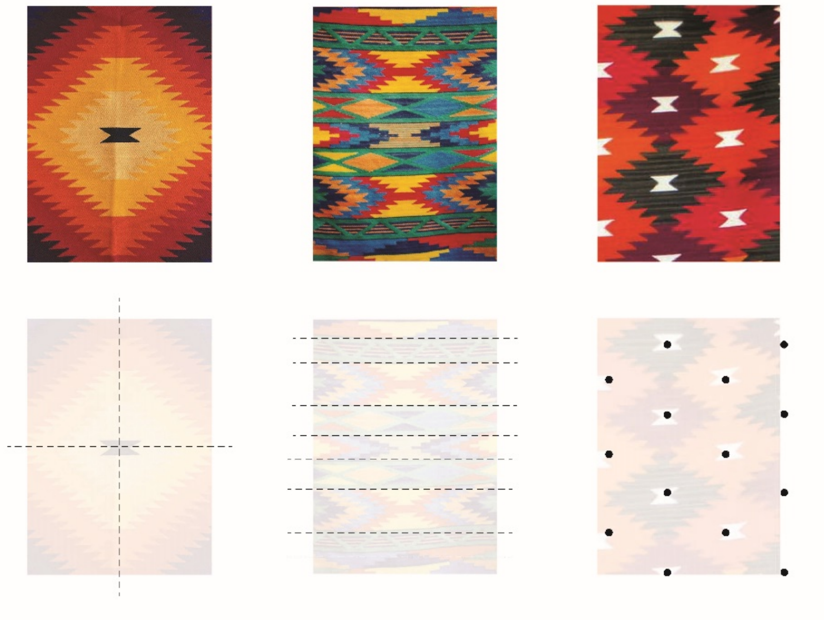

**Figure 2.** Otavalo textiles pattern types: axial (left, from Etsy, 2021), banded (center, from Fashion Pachanga, 2021), and field (right, from Pixabay, 2021).

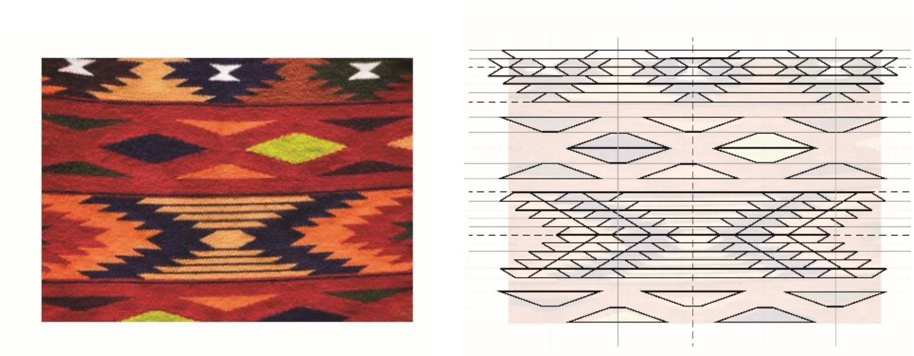

**Figure 3.** Recreation of an Otavalo textile pattern using isosceles trapezoids. (From Depositphotos, 2021).

### 2.2 Shape definition

A series of steps – illustrated in Figure 4 – define a parametric isosceles trapezoid.

a. An initial line of length “x” is created between two points.
b. A copy of this line is translated by “y” units.
c. A copy of the initial line is rotated by “θ” degrees about one of the end points, defining an intersection point between this angled line and the offset line.
d. The angled line is reflected about the center point of the initial line, defining another intersection point between this reflected line and the offset line.
e. A closed polyline is drawn between the four points.
f. This polyline defines an isosceles trapezoid surface.

A digital parametric model is created using the above steps, capable of producing a variety of isosceles trapezoids, controlled by three variables; length “x,” height “y,” and angle “θ.”

### 2.3 Transformations

In order to arrange series of isosceles trapezoids into patterns, shape rules are developed based on observations of relationships between isosceles trapezoids in found Otavalo textiles. These rules are shown graphically in Figure 5. Rules are organized according to basic shape transformations; move, mirror, rotate, and scale.

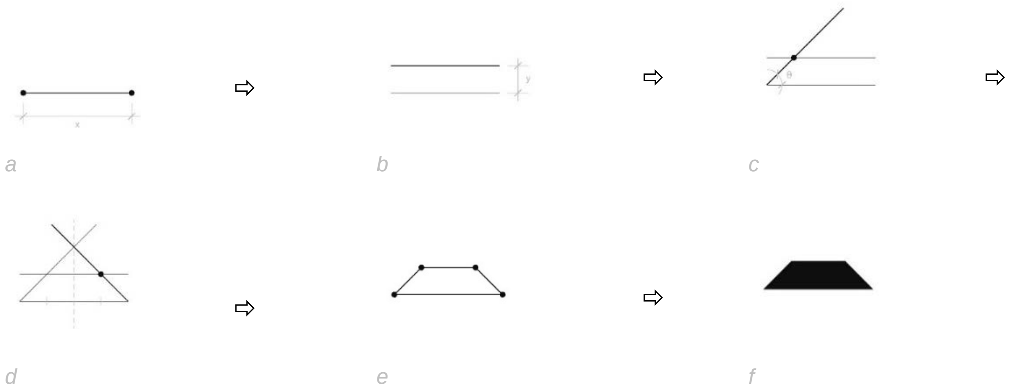


**Figure 4.** Isosceles trapezoid construction.

Rule 0 creates an initial shape. Using Rule 1a, a copy of the initial shape is moved horizontally by an increment equal to the shape width. Whereas using Rule 1b, a copy of the initial shape is moved horizontally by a *variable* amount.

Using Rule 2a, a copy of the initial shape is moved vertically by an increment equal to the shape height. Whereas using Rule 2b, a copy of the initial shape is moved vertically by a *variable* amount.

Using Rule 3a, a copy of the initial shape is reflected about the bottom edge of the shape. Whereas using Rule 3b, a copy of the initial shape is reflected about the bottom edge of the shape and moved vertically by a variable amount. Using Rule 4a, a copy of the initial shape is reflected about the top edge of the shape. Whereas using Rule 4b, a copy of the initial shape is reflected about the top edge of the shape and moved vertically by a variable amount. Certain variables used in Rules 3b or 4b will have the same result.

Using Rule 5, a copy of the initial shape is rotated about a defined vertex by an angle. Using Rule 6, a copy of the initial shape is shifted horizontally and vertically by variable amounts. Observed in found Otavalo textiles, these variables are often 1/2x (one half of the shape length) horizontally and y (equal to the shape height) vertically.

Using Rule 7, a copy of the initial shape is scaled about a defined vertex by an amount larger than 1. Whereas using Rule 8, a copy of the initial shape is scaled about a defined vertex by an amount larger than 0 and less than 1.

Using Rule 9, a given shape can be substituted with a parametric variation of the shape. Rule 10 allows a selected shape to be removed.

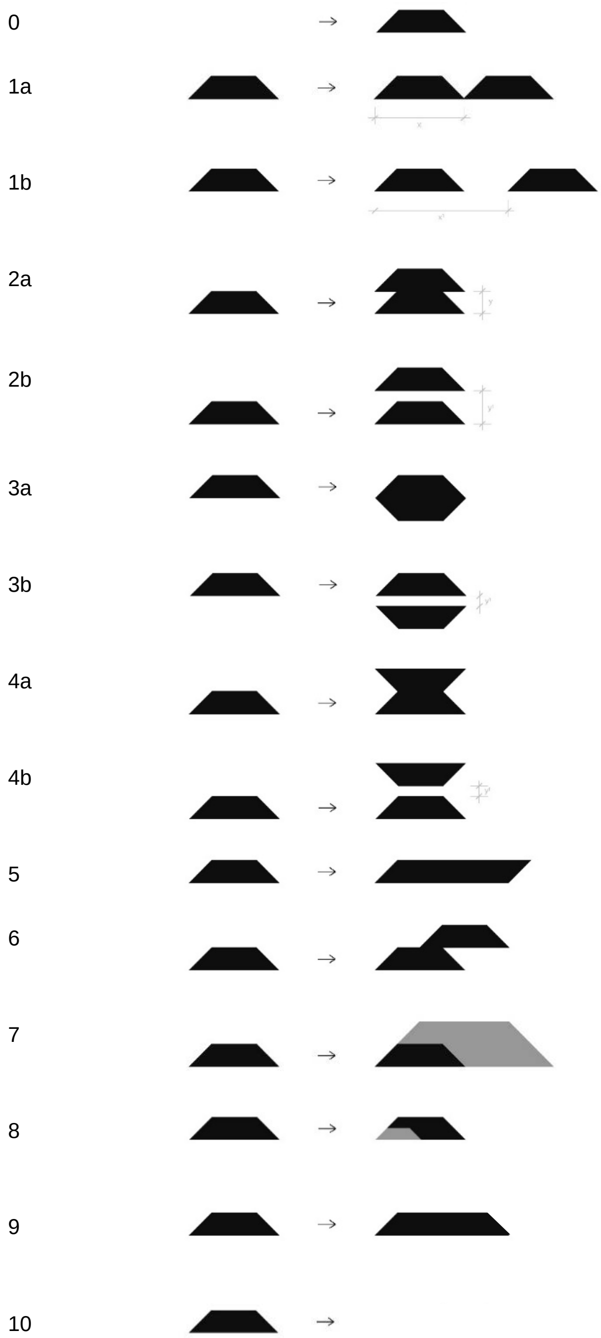


**Figure 5.** Otavalo textile shape rules.

## 2.4 Overlapping and transparency

Using the above shape transformation rules, there are instances wherein certain variables would cause resultant shapes to overlap with initial shapes. For example, when translation amounts are smaller than the initial shape length or height. In pattern productions, rather than full opacity, these shapes are given transparent fill in order to perceive the overlap; creating additional effects, resultant geometry, and opportunities for pattern making.

## 2.5 Production 1: Radial

Shape rules may be used to recreate patterns observed in traditional Otavalo textiles. Figure 6 demonstrates the production of a common radial pattern. First, Rule 4a mirrors the initial shape. A series of repeated shape rotations (Rules 5) and reflections (Rules 4a and 3a) create a horizontal band. Then, Rules 3a, 9, and 6 form a subsequent row. Additional reflections and rotations complete the upper half of the pattern. These steps are repeated to create the lower half.

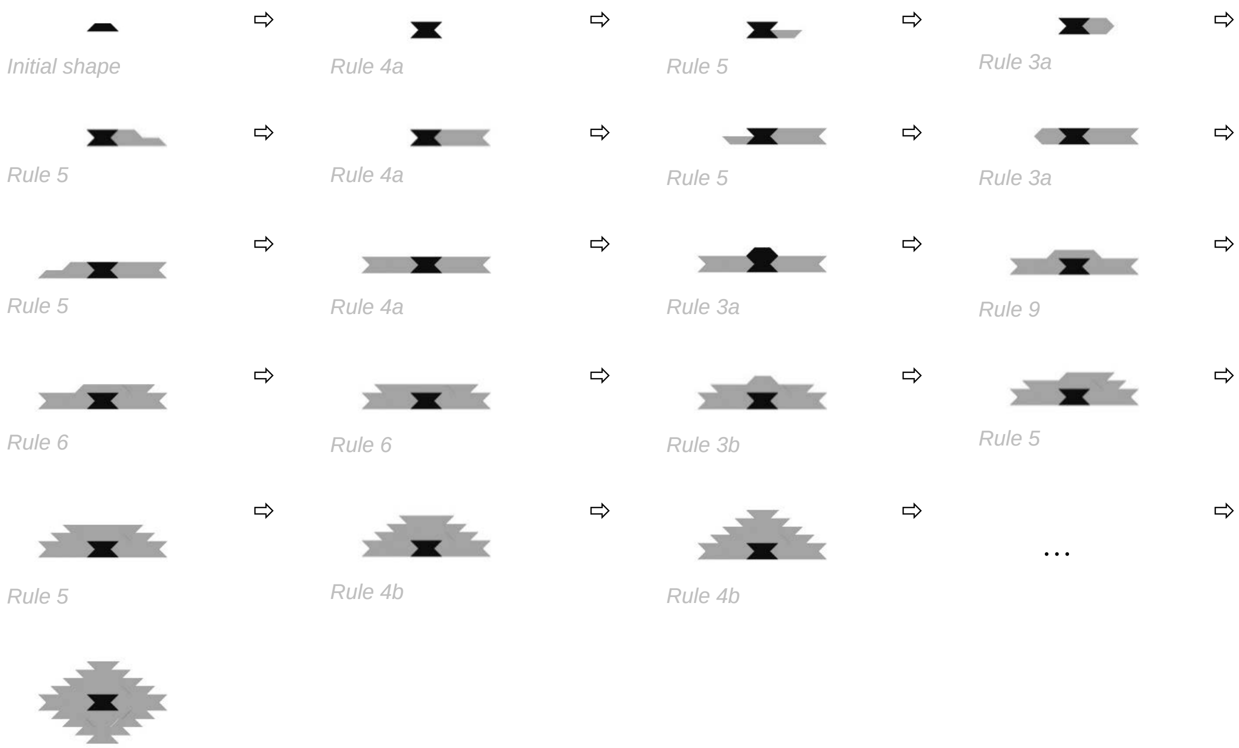


**Figure 6.** Radial pattern production.

## 2.6 Production 2: Array

Figure 7 demonstrates the production of an arrayed pattern using Rules 1a and 2a, distributing a series of shapes across a field horizontally by an increment equal to the shape width (Rule 1a) and vertically by an increment equal to the shape height (Rule 2a). First, Rule 1a is instantiated three times to create the first row. Then, Rule 2a is applied to each isosceles trapezoid in the first row to create the second row. Rule 2a is repeated to produce the desired number of rows.

Alternatively, the resulting pattern in Figure 7 could be replicated and described as: First, Rule 2a is instantiated thirteen times to create the first column. Then, Rule 1a is applied to each isosceles trapezoid in the first column to create the second column. Rule 1a is repeated to produce the desired number of columns.

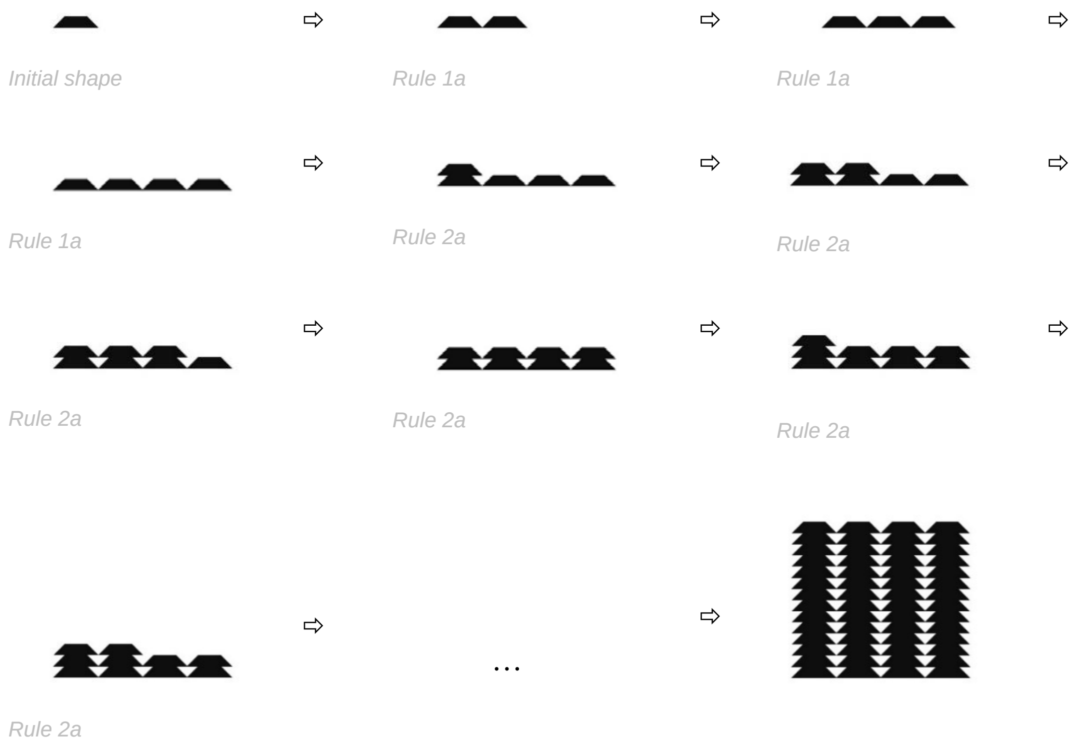


**Figure 7.** Arrayed pattern production.

## 3 Creating new patterns

The process shown in Figure 7 can be replicated using linear array commands. First, the isosceles trapezoid is arrayed four times horizontally by an increment equal to the shape width. Then, this row is arrayed fourteen times vertically by an increment equal to the shape height. (Again, the described order of operations could be flipped; columns then rows.)

As our isosceles trapezoid shape definition, shape rules, and array distributions are created in a linked parametric model, an enormous variety of patterns can be quickly generated and studied. Patterns using additional shape configurations, shape rules, and combinations are illustrated in Figures 8 and 9.

Figures 8a-i use Rules 1a and 2a, demonstrating variations in patterning based on adjustments to shape width, height, and angle. Figures 8j-r use Rule 1b and 2b, varying the amount shapes are moved horizontally and vertically. Figures 9a-f use Rule 3a, 3b, 4a, and 4b, demonstrating patterns with mirrored shape relationships. Figures 9g-l use variants of Rule 5, demonstrating patterns with rotated shape relationships. Figures 9m-o use Rule 6, demonstrating patterns with shifted shape relationships. Figures 9p-r use variants of Rules 7 and 8, demonstrating patterns with scaled shape relationships.

Figures 8c, 8f, 8i, 8l, 8o, 8r, 9c, 9f, 9i, 9l, 9o, and 9r represent anomalies; patterns which break certain rules (alternating rows or columns, non-isosceles trapezoid shapes, random reduce, etc.) but are nevertheless part of the Otavalo textile language.

Based on the above collection of patterns generated digitally, sets of physical models are fabricated to further explore the Otavalo textile shape rules and possible assemblies. Initial physical models remain two-dimensional. In addition to the isosceles trapezoid, other related shapes – triangle and rhombus, which appear as overlapping figures or void spaces in patterns illustrated in Figures 8 and 9 – are also included. Sets of these parts are provided to study participants along with a description of shape rules. Both “solid” and “frame” shapes are represented. Participants are able to use these components to visualize and explore shape rules and develop existing and new patterns more readily with these physical models than digital models (a la Froebel blocks (Stiny, 1980)).

Some students focus on following shape rules, others create departures (shape orientation, reflected stacked rows, diagonal emphasis). Information gathered informs model iterations, shape rules, and example patterns depicted in Figures 8 and 9.

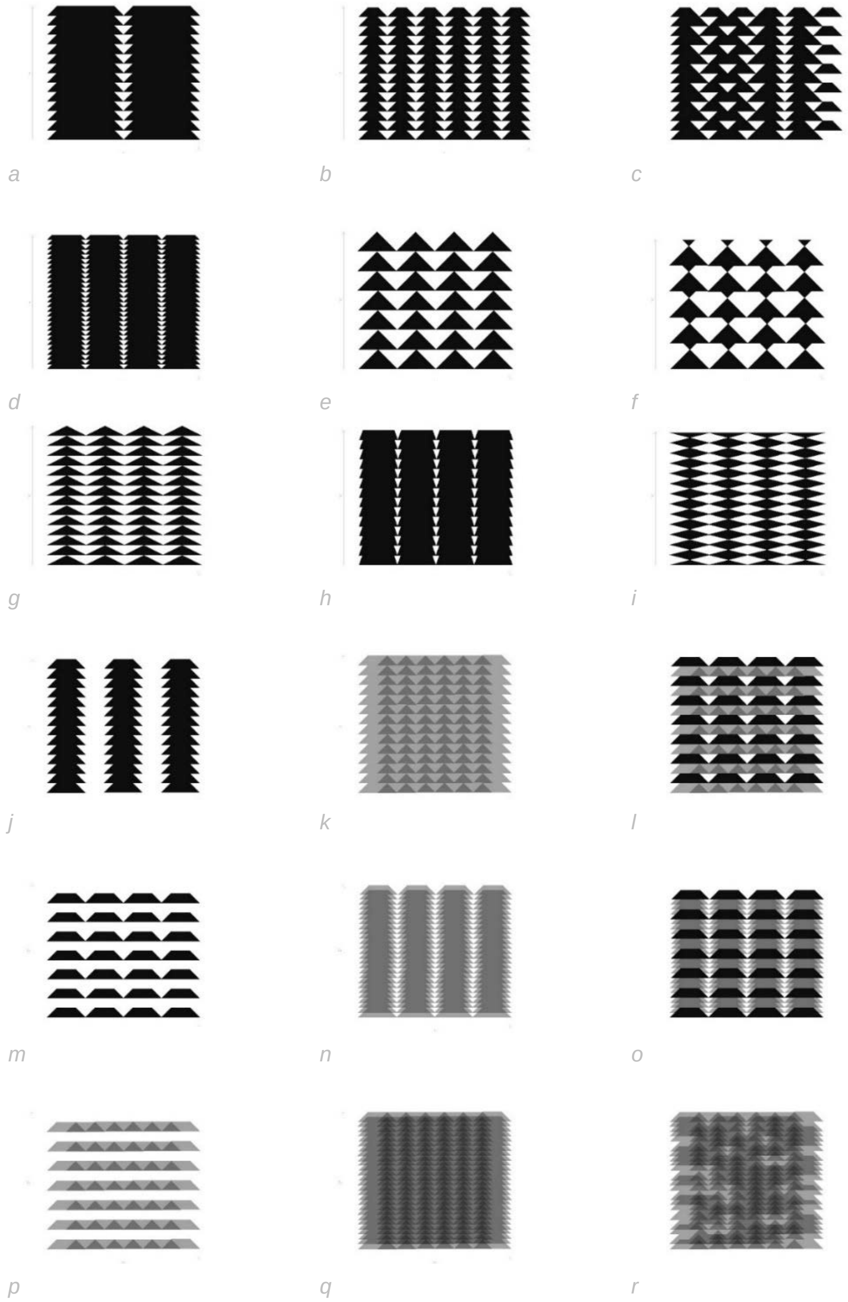


**Figure 8.** Patterns generated using the Otavalo Textile Grammar.

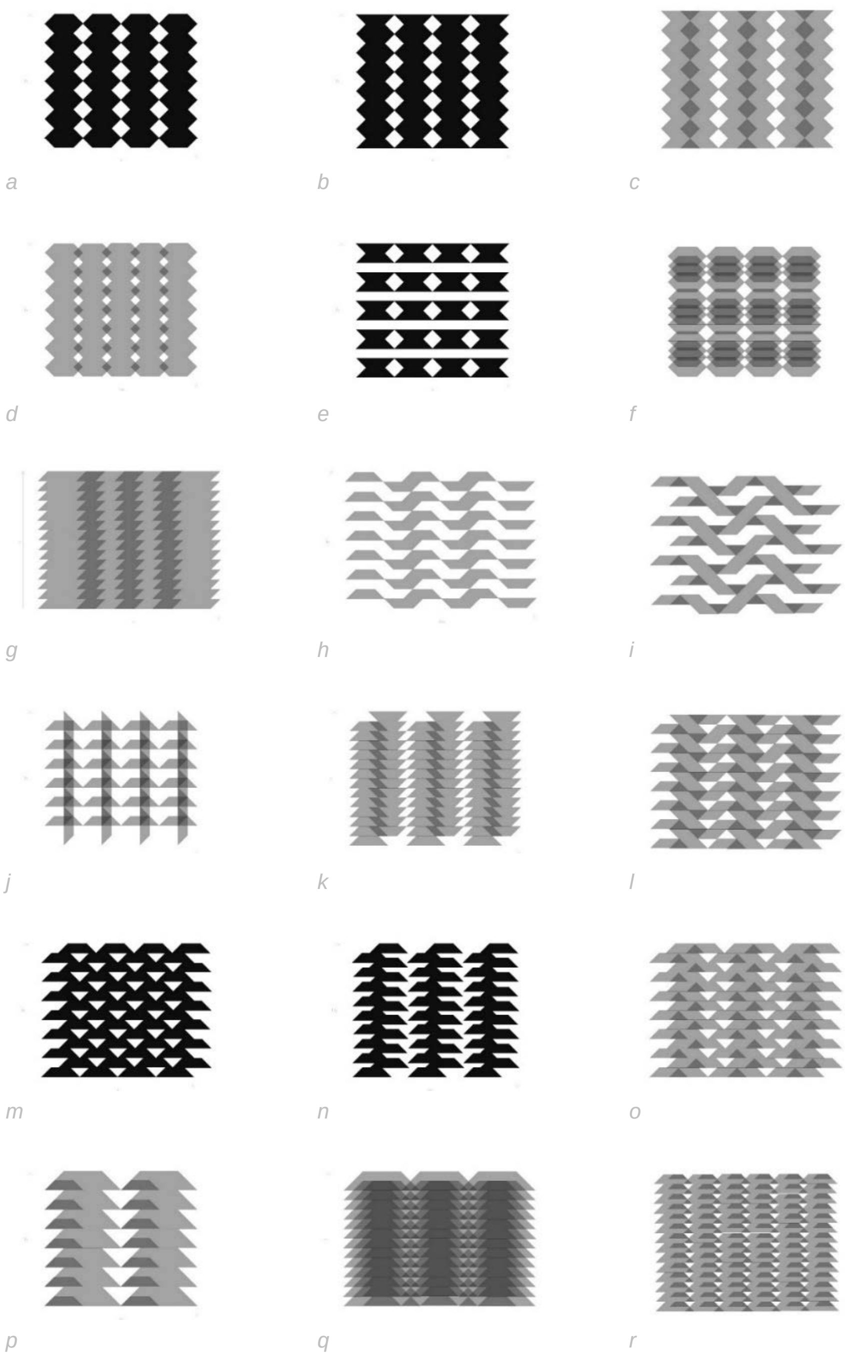


**Figure 9.** Patterns generated using the Otavalo Textile Grammar.

**Figure 10.** Student participants building with spaceframe modules.

## 4 Creating new dialogues

A three-dimensional model is developed and prototyped in order to explore spatial possibilities emanating from the Otavalo Textile Grammar. Modules are composed of laser cut plywood parts assembled into an extruded isosceles trapezoid spaceframe. Design variations studied included extrusion depths, number of layers, and embedded shapes (scaled isosceles trapezoids).

A number of these new building blocks are provided to study participants along with a description of shape rules; a reconsideration of ordinary ways of making. Module assembly sessions are conducted in groups, encouraging students to interact, discuss, and compare constructs; Figure 10.

Group modelling sessions also offer students the opportunity, if comfortable, to share their personal stories; indeed, to share stories of difference.

*a* *b* *c* *d*

**Figure 11.** Example physical constructs.

Completed models – examples of which are shown in Figures 11 and 12 – are analyzed, assembly rules recorded, and pattern syntax defined. Some models exhibit shape rules while others find novel ways for isosceles trapezoid modules to assemble; repetitive stacks, cantilevered elements, various module alignments and densities. Photographs of additional models – shown in Figure 12 – are used to aggregate further patterns; evoking previous two-dimensional physical and digital work.

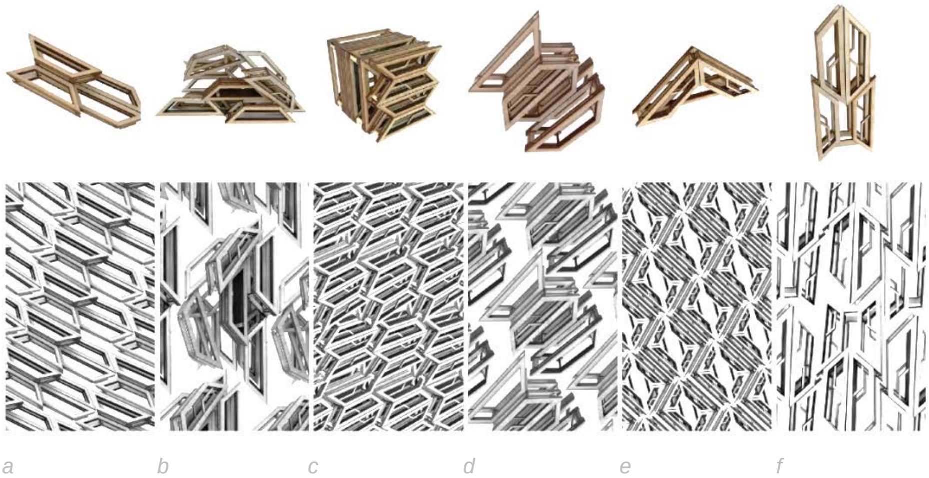


**Figure 12.** Additional physical constructs and corresponding novel patterns.

## 5 Discussion

As the Otavalo Textile Grammar definition and subsequent digital and physical experiments began as a case study for incorporating inspiration from cultural and textile references more meaningfully into architectural design, there is more work to do. This work has focused on one culture, one artifact, and mostly on one shape. There are many more to study and share; more geometry, more textiles, and more stories.

Still, within the context of this study, additional work could investigate effects of the weaving process itself on resultant patterns, limiting shape rules. More iterations of spatial physical models could be developed at defined architectural scales; anomalies defined, proportions considered. If implemented as building facades, environmental performance simulation of various patterns could be conducted. This study has also not yet incorporated analysis of the use and effects of color in found Otavalo textiles.

For now, a final application – illustrated in Figure 13 – incorporates lessons learned from the above three-dimensional study into a proposal for a new pavilion. Like the inspiring textiles, this space aims to be a place for sharing stories. Following the programmatic framework for just public spaces set by Low and Smith, the design strives for a) representation of people's histories, b) acknowledgement of existing conditions or activities, and c) economic and cultural access. (Low and Smith, 2021)

Reflecting on this work, it is clear that this is not simply a geometric study. Through a shape grammar methodology, participants expressed personality and learned cultural history. This in turn stirred a questioning of typical construction, leading to an appreciation of architectural expression as a spatial and social undertaking. Parametric models enabled quick design variations and decisions. Then, physical models allowed participants to make choices in the placement of modules; agency over place to share part of their identity. We seek more of this experience in architectural education and practice.

**Figure 13.** Pavilion proposal rendering.

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