

Math in Tlingit Art:

A Culture-Based Technology and Mathematics Project for K-12 Classrooms in Southeast Alaska

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## Abstract

The Math in Tlingit Art project merges Tlingit basketry with mathematics and technology. Project participants study baskets learning cultural stories and Tlingit language for designs, weaving techniques, and materials. The geometric shapes in the basket patterns make ideal LOGO projects. LOGO is a user-friendly programming language designed for K-12 classrooms, where students use mathematics to navigate the turtle about the computer screen. In this project students create LOGO procedures for repeated units in the geometric patterns. Complete basket patterns are constructed in LOGO super procedures, which position and repeat the geometric shapes on the monitor screen. Students learn the Tlingit cultural meaning and stories surrounding baskets, and explore mathematical properties of shapes, patterns, angle turns, distance, and symmetry.

The Third International Mathematics and Science Study (2000) has created a new wave in mathematics education designed to upgrade the mathematics skills of K-12 students throughout the US. Alaska has joined this effort and instituted Benchmark Exams for students in grades three, six, and eight; High School Qualifying Exam was instituted for students in 10<sup>th</sup> grade. These exams measure the effectiveness of curriculum and instruction and provide individual school ratings. (Perfection Learning Corp., 2002) After comparing the Benchmark Exam scores of for the 2000 and 2001 academic years, Shirley Holloway, the Commissioner of the Department of Education and Early Development (DEED), was encouraged by the slight increase in test scores. She felt Alaska’s education was moving in the right direction. However, she expressed concerns over the scores of Alaskan Native students. Holloway said, “While the percentage of Native students performing at the proficient and advanced levels has grown, the learning gap is still there. To eliminate the learning gap will require a deep commitment from all of us – parents, teachers, school board members, policy makers, businesses, everybody.” (Holloway, 2002, Pg. 2)

Review of the data on mathematics tests scores from the 2001 Benchmark Exams reveals a 30% – 35% achievement gap for Alaskan Native students, who performed below White students in math scores for grades three, six, and eight. However, both White and Alaskan Native students are declining in mathematics achievement as they progress from grades three to eight. (Holloway, 2002)

Table 1. Degree of Math Proficiency by Ethnicity and Grade Level

Grade	Ethnicity	Advance/ Proficient	Below/Not Proficient	Ethnicity	Advance/ Proficient	Below/Not Proficient
3	AK Native	49.7%	50.3%	White	81.1%	18.8%
6	AK Native	39.4%	60.6%	White	75.9%	24.1%
8	AK Native	20.0%	80.0%	White	50.4%	49.6%

Does this decline continue through high school? In Table 1 look at the declining percentages of Advance and Proficient mathematics test scores over the advancing grade levels. We must ask what percent of Alaskan Native students will pass the High School Graduation Exam and receive high school diplomas? The trend in math scores as Alaskan Native students advance to 10th grade and beyond does not look promising. The trend for White students is more promising but certainly not satisfactory. It is time for some serious intervention in mathematics education for all of Alaska's students.

In 1994 Herb Clemens of the University of Utah Mathematics Department and Claudette Engblom-Bradley designed the "Ndahoo'aah program at Monument Valley High School, Utah. The project, which was designed for Navajo students, employed four Navajo elders, who were rug weavers, loom beadwork makers, and coil basket makers. Navajo students learned to weave under the careful mentoring of the elders. The elders spoke Navajo to the students while they explained the details of weaving. They also told Navajo folk tales about weavers, as well as, their personal stories of learning to weave. (Rickenbrode, 2000)

The students learned the designs in the crafts and reproduced them on paper to bring them into the LOGO Computer Laboratory, where they programmed the designs on the computer. LOGO is a user friendly, computing language that is compatible with human learning. In the LOGO laboratory, students learn to navigate the turtle about the monitor screen, type procedures and create new procedures for the turtle to learn. (Bradley, 1993; LOGO Foundation, 2000) As students use mathematics to plan their designs and navigate the turtle on the monitor screen, they discover new mathematical ideas, which in turn, reinforce their preexisting ideas.

The 'Ndahoo'aah program operated for 3 1/2 weeks every summer for 6 consecutive summers. It engaged community members of all ages in school events, increased the number of computer laboratories, and inspired growth in the bilingual education programs offered to Monument Valley High School students. (Rickenbrode II, 2000; Engblom-Bradley & Reyes, 2004)

Andy Hope, Southeast Alaska Coordinator for the Alaska Rural Systemic Initiative, Engblom-Bradley decided to develop a similar program in Juneau, Alaska. They hoped to impact Alaskan Native students' interest and skills in mathematics. Hope knew Tlingit weavers and linguists and negotiated with the Chatham School District and Juneau School District to send teachers to a summer workshop, that would provide weaving and LOGO computing instruction for teachers. In exchange, the teachers would develop mathematics curriculum to engage their students in weaving and LOGO programming of Tlingit basket designs. Teri Rofkar, an accomplished weaver, provided the weaving instruction and Engblom-Bradley provided the LOGO instruction. The institute started with four teachers each from Chatham School District and Juneau School District, who enrolled in a graduate level course, designed for the project. The course was entitled, Math in Tlingit Art. (Fry, 2003; Hope, 2003)

Tlingit people in Southeast Alaska live in an area that spreads from Ketchikan to Yakutat Bay. Their baskets are made of split spruce root with false embroidery designs (Cory, 1995). The designs are generally geometric patterns that repeat around the sides of their cylinder shapes. The designs have red, black, grey and vanilla colors against the natural tan fibers of the spruce root. They are woven with dyed wefts over horizontal bands. The right angle shapes are ideal for beginning LOGO projects. Students experience less confusion in creating right angle shapes for the exterior angle and interior angles, which are both 90 degrees.

This program blends Native culture regarding basketry with Mathematics and technology for the K-9 classroom. The teacher has the option to invite a weaver to teach weaving to the children and share stories and cultural knowledge about baskets. Or, the students could explore the cultural aspects of basketry through resources, like the Internet, or school Library. The Alaska Native Knowledge Network has listed many resources on their website for this project to provide easy access for teachers. (ANKN, 2004; Hope, 2003)

Rofkar is a recognized Tlingit weaver who has sold her work since 1986. She is an employee of Sitka Museum in Sitka, Alaska, where she conducts museum tours and weaves Tlingit baskets, Chilkat Blankets and Raven's Tail. She is from the Raven Clan in the Snail House. Her Tlingit name is Chas' Koowu Tla'a from the T'ak dein taan Clan. Her lineage dates back a thousand years along the Northwest Pacific coast of Alaska. She visits the trees, which are also thousands of years old and have known her ancestors. Spirits of the trees share their wisdom and provide Teri with comfort and strength to continue her weaving. "My weavings are a reflection of an ancient relationship rekindled." (Rofkar, 2000)

Chilkat Blankets are woven with the patterns of the Tlingit totem poles. They are woven in secret and presented as an entity with a spirit of their own. The blanket dances and needs the sounds of the singers, as much as, the surroundings of the mountains and ocean waters to nourish its spirit. (Chilkat, 2004)

Raven's Tail is a woven blanket or skirt. The weave is similar to the spruce root baskets. The yarn hangs down and the weaver controls the tension. The weaver generally takes one hour to weave one row, thereby making the task of weaving a Raven's tail blanket equivalent to 600 to 2000 hours for the entire blanket. The geometrical patterns woven into the blanket tell a story, just like a totem pole. (Rofkar, 2004)

Rofkar introduced the concept of splitting spruce roots with packages of string cheese. Students could practice splitting spruce roots by splitting string cheese. In addition to eight students, who were teachers from the Juneau and Chatham School Districts, two linguists, Richard Dauenhauer and Nora Dauenhauer and one faculty member from UAA, Engblom-Bradley also participated as students to learn how to weave. Rofkar brought materials that were easier to gather and appropriate for K-9 students to learn weaving skills. The participants received Yogurt cups and yarn. Under Rofkar's direction, the cylinder sides of yogurt cups were cut vertically towards the bottom's circular edge. The cylinder side was cut into equal halves to insure the spacing between the vertical cuts was uniform. The halves were cut into equal halves, thereby yielding four sections. Each fourth was cut in half to yield eight sections. Each section was cut in half to yield 16 equal sections. The sections were wefts for the yogurt-yarn basket. The yogurt cup could lie flat on the table with 16 spider legs surrounding the circular base.

Rofkar began the weaving carefully with the 36-inch yarn string. The participants followed her instructions wrapping the yarn around a weft at the circular base of their yogurt cups and started weaving two strands of yarn. The strand in front is wrapped over the strand from behind the weft and behind the next weft. This weave is repeated and the yarn strands spiral up the sides of the wefts to complete a basket. At some point the weaver switches yarn colors to insert a pattern in the basket.

When the teachers completed a yarn-yogurt-cup basket, they began a yarn-pipe-cleaner basket. Pipe cleaners allowed them to begin a basket with the interlocking weave used by Tlingit basket makers. The basket bottom began with 8 pipe cleaners with 4 vertically placed and 4 horizontally. One vertical pipe cleaner was woven over-under-over-under the 4 horizontal pipe cleaners. The next pipe cleaner was woven under-over-under-over and the third and fourth pipe

cleaners repeated this weave. The 16 pipe cleaner ends formed a weft for the basket. The yarn was wrapped around one weft and woven around the 16 wefts forming a circular base for the basket. The basket maker had to be careful to adjust the tension to keep the base flat and to tighten the tension when the basket was to curve upward and become the side of the basket.

It was harder to control the tension for the yarn-pipe-cleaner baskets. Some baskets curved inward giving the basket a hyperbolic shape. The wefts would bend and twist like spider legs. The teachers wondered how this unruly object would ever become a basket. The baskets were completed and everyone was satisfied with their works of art.

Lori Hoover of Riverbend Elementary in Juneau, Alaska, teaches 2<sup>nd</sup>/3<sup>rd</sup> grade students. “We have been doing some pre- learning of skills before going to the software. We have spent time on symmetry and reinforcing vocabulary needed.” (Hoover, 2003, p. 1) Using colorful construction paper her students traced and cut multiple copies of the letters in their first name. For horizontal line symmetry they glued the letters on black construction paper, then glued a second copy of each letter below the matching letter and upside down to form a lake view mirror image of their name. For vertical line symmetry they glued the second copy of each letter in reverse order continuing from left to right. For rotational symmetry they glued four copies of their name clockwise at 90-degree angles of the previous copy.

Using The National Library of Virtual Manipulatives via Internet Hoover’s students created colorful Pattern Blocks symmetric patterns. The students copied their virtual patterns with pattern block stickers on construction paper. They found this activity to be satisfying, and it reinforced their notions of symmetry. (Hoover, 2003)

The students explored symmetry in Tlingit designs along with their cultural meaning. The Backbone resembled the backbone of a salmon. The spinal center was the horizontal line of

symmetry with slanted parallel rib bones reflecting on both sides of the spinal center. Butterfly in Flight pattern is a glide-reflection, side-view image. The wings are up, then flip down, then up, then down, and so on. The on-looker must imagine the butterfly flying. The Eye is a rhombus with a vertical and horizontal line of symmetry, which is also the diagonal of the rhombus. (Hoover, 2003)

The original robotic turtle was a 15-inch diameter clear plastic hemisphere with two 4-inch wheels on opposite sides. The electronic mechanism inside the hemisphere was visible with a wire connection to a mainframe computer. A felt-tip pen was inserted in the bottom center of the turtle to draw on the butcher paper beneath it. The user operated the turtle with a button box. Pressing Forward 30 moved the turtle forward 30 turtle steps. Pressing Right Turn 90 turned the turtle 90 degrees in the clockwise direction. Repeating these two procedures 4 times would cause the turtle to draw a square on the butcher paper beneath it. The user could press four additional buttons: Pen Up, Pen Down, Left Turn #, and Back #. With the 6 basic procedures the user navigated the turtle about the butcher paper causing the turtle to draw geometric shapes and lines if the pen was down or causing the turtle to move about the screen if the pen was up. Users could organize games or mazes by placing wooden obstacles on the butcher paper and planning to navigate the turtle to avoid knocking down the obstacles. (LOGO, 2003)

In 1975, the turtle was placed on a monitor screen. Its Home position is the center of the screen. The user types:

FD 50 for Forward 50,  
BK 40 for Back 40,  
RT 60 for Right Turn 60 degrees clockwise,  
LT 60 for Left Turn 60 degrees counterclockwise,  
PU for Pen Up,  
PD for Pen Down, and  
Home to return the turtle to the Home position in the center of the screen.

These procedures allow the user to navigate the turtle about the monitor screen. (LOGO, 2003)

Hoover's students needed to relate to the turtle. They simulated turtle behavior by playing Blind-Fold Turtle and Dinosaur Turtle. Safe obstacles are placed on the classroom floor. A student is blind folded; another student tells the blindfolded student how to move with LOGO procedures to the opposite side of the room without bumping into the obstacles. New versions of Blind-Fold Turtle evolved. Two or more students are blindfolded and take turns receiving procedures how to move across the room without bumping into obstacles or each other.

Dinosaur Turtle require two players with Square Inch grid paper. Each player has a dinosaur figure to move about the grid. Students read LOGO procedures on a card and move their dinosaur accordingly. The first to reach the other side of the board is the winner. (Hoover, 2003)

Students are ready for LOGO programming. When new LOGO page is opened, a turtle shape appears in the center (HOME) on the monitor screen. The user talks to the turtle by typing instructions (procedures) on the keyboard. Their first project is to teach the turtle to make a square. The user tells the turtle to move forward 50 pixels (FD 50), turn right 90 degrees (RT 90) and continues typing these procedures three more times:

```
FD 50
RT 90
FD 50
RT 90
FD 50
RT 90
FD 50
RT 90
```

After typing each procedure, the user presses <return> and the turtle moves accordingly. When done, the turtle has drawn a closed figure, known as a square.

Typing 8 procedures each time the user wants the turtle to draw a square is labor intensive. Students must create a new procedure (SQUARE). This new procedure begins with TO, a space, and SQUARE. In subsequent lines students type the 8 procedures, which tell the turtle to make a square, and finish by typing END.

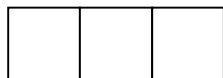
```
TO SQUARE
FD 50
RT 90
FD 50
RT 90
FD 50
RT 90
FD 50
RT 90
END
```

From then on the student tells the turtle to draw a square by simply typing SQUARE. This is how students teach the turtle new words.

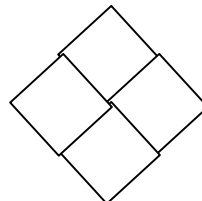
Students use SQUARE to make designs. A flag is a line plus a square. The user types FD 50 SQUARE, presses <return> and the turtle draws a vertical line and square.



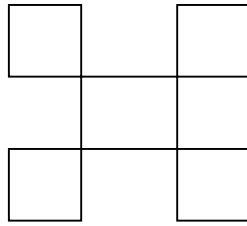
Three horizontal squares are constructed by rotating the turtle 90 degrees, drawing a square, moving the turtle forward 50, drawing a square, moving the turtle forward 50 and drawing a square.



Four diamonds inside a diamond are constructed by rotating the turtle 45 degrees, drawing a square, and repeating three times: RT 90 SQUARE.



A five square X pattern is created by rotating four flags counterclockwise: moves the turtle forward 50, draw a square, repeat three times turning the turtle left 90 degrees, move it forward 50 and draw a square.



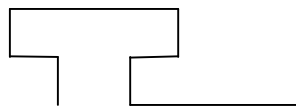
These simple designs give students practice using a procedure (SQUARE) to make designs. (Rickenbrode, 2000)

LOGO is the most user-friendly computer language, for it was developed with the direction of a mathematician, Seymour Papert, who also studied under Jean Piaget in Switzerland. The development of LOGO procedures parallels the development of language in human beings. (Papert, 1999) The classroom experience of teachers in the Math in Tlingit Art project supports the user-friendly concept of LOGO. Ryan Dorsey is the 9<sup>th</sup> grade teacher in Angoon, Alaska. Dorsey introduced LOGO to his students, who readily mastered the computing skills needed for LOGO programming. “I have been using LOGO for two weeks now with my students. Some are doing very well.” (Dorsey, 2003, p. 1)

Traditional Tlingit Baskets were made of spruce roots, which were split into very thin strips for a fine weave. The spruce roots were dyed bright colors. The designs were woven on the outside surface, so the weave was not visible on the inner surface of the baskets. Natalie Linn, a basket expert, describes a very beautiful and large Tlingit basket with repeating rhombus shapes round the middle and two large repeating “T” shaped patterns above and below the rhombus shapes. The “T” patterns are connected and, when held upside down, result in the same pattern. The “T” pattern is a glide reflection. (Mimbres, 2002)

(Figure 1 – Spruce Root Basket)

The “T” shaped pattern woven on the Tlingit basket is an interesting LOGO project. Prior to programming, the student makes the “T” shaped pattern on dot matrix paper. This allowed them to view the details of the pattern, realizing the repeating unit. (See Figure 2) Now students are ready to make the “repeating unit” on the geoboard. They place the elastic bands about the pegs, which teaches them to feel and see directions needed to navigate the turtle. Placing the elastic bands on the geoboard provides the kinesthetic and visual understanding for navigating the turtle. The turtle is navigated up the “T” stem, around the rectangular “T” top, down the “T” stem and turned left to make a long horizontal line, which is the basis for drawing the “T” unit pattern.



The programmer/student creates the repeating “T” unit as a LOGO procedure (TEE) with the turtle turned left 90° at the end. This gives the turtle an upward orientation, which positions the turtle to start another “T” shape. As you might suspect this process would challenge some children, who would make several tries before mastering the tasks.

In LOGO the unit pattern, TEE, is repeated with a REPEAT statement. The student creates a super procedure (BORDER), which tells the turtle to draw TEE eight times on the monitor screen. (Bradley, 1993)

```
TO BORDER  
REPEAT 8 [TEE]  
END
```

(Figure 2. – Border pattern)

The students in Lori Hoover’s class created LOGO projects from Tlingit Basket Designs. A 3<sup>rd</sup> grade student constructed the “T” pattern. Her “T” unit was defined as “t”. The super

procedure was “ three t pattern,” which repeated “t” three times. (See Figure 3) Another child made a cross pattern with three “U” shapes. His “u” procedure made a three-sided open-square shape with the turtle turned left ninety-degrees at the end. His super procedure, “cross” repeated “u” four times. (See figure 4)

The Grid and Cockleshell pattern was a popular Tlingit pattern chosen by the students to weave in their yarn-yogurt cup baskets. The design alternated two colors. The student created two procedures: “vert” and “hors”. “Vert” made the turtle draw 14 vertical lines and “hors” made the turtle draw eight horizontal lines. His super procedure, “grid” told the turtle to draw the vertical lines and then turn right ninety degrees to draw the horizontal lines. Then the student filled the red color in seven columns alternating with six white columns. This action completed the Cockleshell pattern, which many children had woven into their yarn- yogurt-cup baskets. (Hoover, 2003)

(Figure 3, 4, 5 – Student Pattern)

The Hohka pattern is popular in Navajo Blankets and appears in Tlingit baskets. (Bradley, 1993) The rhombus pattern has four sides, which are stair steps. Many times the steps are elongated in either a horizontal or vertical direction. The students create the pattern with the rise and run of the steps equal in length. However, with the introduction of variables for the lengths of the rise and run the Hohka pattern can be elongated in either direction to match the design on a particular basket.

(Figure 6 – Hohka Pattern)

After programming the designs, students prepared to weave baskets using colorful yarn and yogurt cups. They planned their designs on graph paper, and determined the number of warps in the design. Their warps were the vertical plastic strips that the students needed to cut

into the yogurt cup. They estimated the number of rows woven with yarn that their pattern would need.

Hoover had all students weave the Cockle Shell pattern for their first yarn-yogurt basket in an attempt to insure success. This pattern requires dark and light colored yarn on alternate warps. The students could see the pattern quickly. Weaving became “contagious”! Hoover’s students wove over 100 baskets with various designs. They searched their family’s refrigerators to find plastic containers of all sizes, margarine tubs, humus-spread containers, and Kentucky Fried Chicken buckets. (Hoover, 2003)

Tlingit designs have many geometric shapes, including squares, rectangles, parallelograms, and triangles. The designs illustrate geometric transformations: translation, reflection, rotation, and glide reflection. Planning the design on graph paper presents issues of rectangular coordinates that include vertical and horizontal positions of the design parts, which are related to wefts and rows in the baskets. Students must transfer designs into LOGO projects. They engage in spatial visualization and navigation problem solving. The turtle is navigated about the monitor screen using angles and proportional distances. They must determine the degrees and direction (i.e., left or right) of each angle turn for the turtle. They must cut vertical wefts of uniform width in the cylindrical surface of the plastic yogurt cups. They make a first cut and the second cut starts halfway around the rim. The two half sections are cut in half, thereby creating four equal sections. The fourths are then cut in half to create eight equal sections. The students may stop at eight sections or continue to make 16 or 32 equal sections. The students determine the number of sections based on the desired fineness. Hoover’s students were encouraged to cut 8 wefts for the first yarn-yogurt cup basket. (Hoover, 2003)

Topaz Shryock teaches for the Juneau School District. “My 8th graders are doing a great

job, but my 7th graders are struggling a little bit because some of the math introduced is so new to them”. (Topaz, 2003, p. 1) At all levels of this project, students are engaged in Mathematical problem solving: the symmetric patterns of Tlingit designs, the coordinates of the graph paper and the basket, the navigation of the turtle, and the fineness of the weft. Students are discovering mathematics and reinforcing the mathematics they already know, they use mathematics in each step of the process. For Alaska Native students, connecting mathematics to a familiar cultural artifact means that their ancestors engaged in mathematical thinking. They learn that mathematics is not just artifact of western thought, but that it is also embedded in the cultural ways of Alaskan Native people.

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Figure 1. Tlingit Spruce Root Basket  
Source: "Baskets of the Northwest People"  
<http://www.mimbresfever.com/north.html>



Figure 2: The repeating unit looks like a “T”  
 Source Rickenbrode II, (1995-2000)

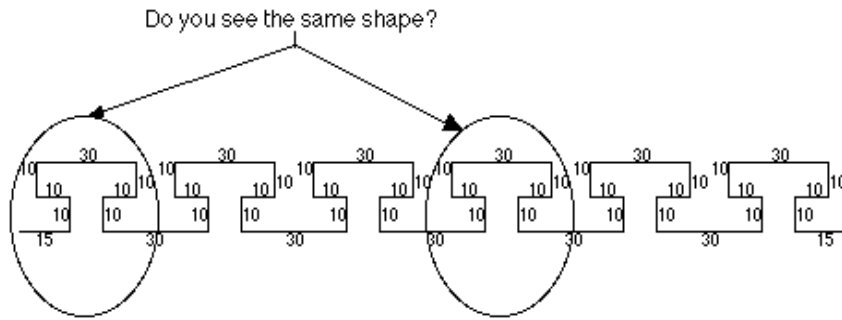


Figure 3: The «T» Pattern  
 Source: (Hoover, 2003)

### The “ T ” Pattern

```

to t
pd
fd 60
lt 90
fd 70
rt 90
fd 30
rt 90
fd 160
rt 90
fd 30
rt 90
fd 70
lt 90
fd 60
lt 90
fd 180
lt 90
end
                    
```

to three t pattern  
repeat 3[t]

Figure 4: U and Cross Pattern  
Source: (Hoover, 2003)

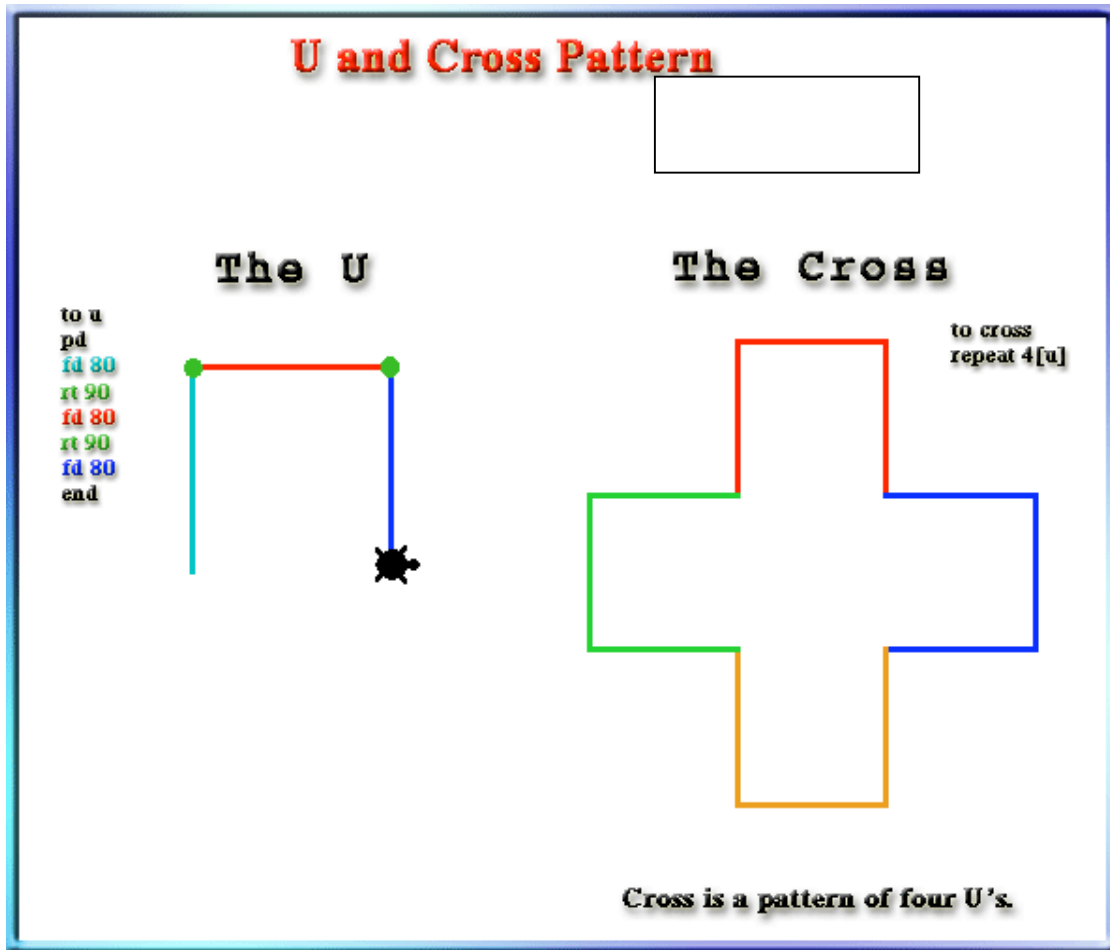
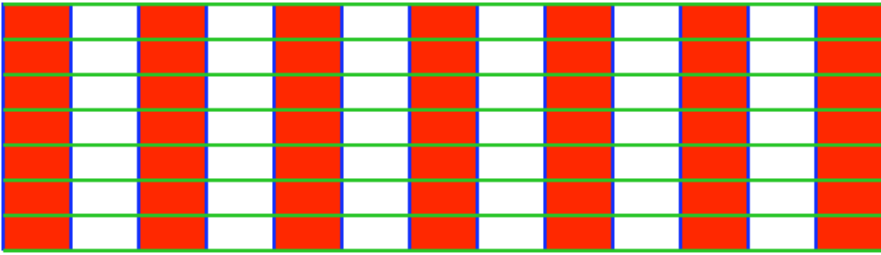


Figure 5: Grid and Cockleshell Pattern  
Source: (Hoover, 2003)

### Grid and Cockleshell Pattern



A grid is  
vertical lines...

```
to vert
pd
fd 260
pu
rt 90
fd 40
r90
pd
fd 260
pu
rt 90
fd 40
lt 90
pd
end
```

and  
horizontal lines...

```
to horz
pd
fd 560
pu
rt 90
fd 20
rt 90
pd
fd 560
pu
lt 90
fd 20
lt 90
pd
end
```

drawn together.

```
to grid
repeat 7[vert]
rt 90
repeat 4[horz]
end
```

Figure 6: Stair and Hoka Patterns  
Source: (Hoover, 2003)

