CHAPTER SEVEN

Chicanos Have Math in Their Blood

Pre-Columbian Mathematics

BY LUIS ORTIZ-FRANCO

Mathematics education dates its beginnings to the time when human beings began to quantify the objects and phenomena in their lives. Although the process of counting (one, two, three...) was the same for different groups of people around the world, the symbols by which they represented specific quantities varied according to their own particular cultural conventions. Thus, the Babylonians, Romans, Hindus, Egyptians, Angolans, Chinese, Aztecs, Incas, Mayas, and other groups each wrote numbers differently.

Likewise, cultures that achieved a level of mathematical sophistication that allowed them to manipulate their number symbols to add, subtract, multiply, and divide and to perform other algorithms did so in different ways. Today, even within a single society, various groups of people (for example, accountants, physicists, engineers, mathemati-

cians, chemists, and so on) view and manipulate mathematical quantities differently from one another. The study of the particular way that specific cultural or ethno groups — whether they are different national, ethnic, linguistic, age, or occupational groups or subgroups — go about the tasks of classifying, ordering, counting, measuring, and otherwise mathematizing their environment is called ethnomathematics.

The ethnomathematics of pre-Columbian cultures is a topic frequently overlooked in discussions about the cultural achievements of pre-Columbian civilizations, and omitted from college-level textbooks on the history of mathematics. It is important that we focus on pre-Columbian mathematics: Such a focus broadens our perspectives on pre-Columbian cultures and may stimulate us to integrate new perspectives and topics into our classroom teaching. The ultimate beneficiaries of these educational practices will be North American society in general and North American children in particular.

The integration into school mathematics of pre-Columbian mathematics is important for both political and mathematical reasons. The teaching of the mathematical traditions of pre-Columbian cultures can contribute to achieving a crucial political goal: infusing multiculturalism into education. Students will thereby develop an appreciation for the diverse ways different cultures understand and perform mathematical tasks. This will expose students to the sophisticated mathematical traditions of other cultures and demonstrate that performing mathematics is a universal human activity.

For Chicano students in particular, studying pre-Columbian mathematics will allow them to learn more about their ancestors in both cultural and mathematical contexts. This integrated approach can do much to instill pride in their culture and also increase their confidence in their ability to learn and do mathematics and, perhaps, later participate in mathematics-based careers.

Chicanos are mestizo, a blend of European and Mexican Indian ancestry. In this country, the cultural roots of Chicanos in pre-Columbian cultures are acknowledged at the social level but are usually ignored in the American educational system. In a scene in the movie *Stand and Deliver*, teacher Jaime Escalante attempts to motivate his Chicano mathematics students at Garfield High School in East Los Angeles by saying: "You burros have math in your blood." Escalante's comment surely will seem sadly ironic to readers familiar with the statistics regarding the low educational achievement of many Chicano students, and familiar with both the history of mathematics in Maya and Aztec societies and the relatively minuscule number of Chicanos who pursue mathematics-based careers in the United States.

Chicanos' impressive history of cultural achievement has been almost entirely ignored in U.S. schools.

Despite a long and distinguished heritage in the sciences, arts, and letters in their own culture, Chicanos are one of the least educated groups in this country. Their impressive history of cultural achievement has been almost entirely ignored in U.S. schools for at least two reasons. First, the Western orientation of the educational process largely disregards the achievements of conquered indigenous civilizations and their descendants, such as Mexican people. Second,

as a result of this ethnocentric orientation, many teachers and other school officials in the United States are unaware of the mathematical accomplishments of pre-Columbian societies.

This article discusses a pre-Columbian number system that played an important role in the cultural activities — such as commerce and dating historical events — and the development of Mesoamerica. (The term "Mesoamerica refers to the geographical region that encompasses the area from northern-central Mexico to northern Costa Rica.) In this essay, I discuss the Mesoamerican number system and the origins of the vigesimal number system, and make some instructional suggestions.

The Mesoamerican Number System

The Mesoamerican number system is a positional vigesimal (that is, base 20) system. It employs only three symbols to write any whole number from zero to whatever quantity is desired. This symbol represents 0:

The dot represents the quantity of 1: •

And the horizontal bar represents the quantity of 5: ▬

To write the numbers 0 to 19 in this system, the two processes of grouping and addition are used. Numbers 2 to 4 are written using an addition process. For the number 5, five dots are grouped into a horizontal bar. Numbers 6 to 19 are written using the addition process (see Figure 1).

For numbers larger than 19, a vertical positional convention is used (see Figure 2). In this convention, the bottom level is for the units, the next level up is for the 20s, the third level up is for the 400s (1 x 20 x 20), the fourth level up is for the 8,000s (1 x 20 x 20 x 20), and so on in powers of 20. For instance to write 20, we write the symbol for 0 in the first level and a dot in the second level. To write 65, we write three dots in the second level (3 x 20 = 60) and a horizontal bar, representing five units, in the first level.

This vigesimal system of numeration is practical to use and can easily be adapted to classroom instruction. For example, the operations of addition and subtraction are relatively straightforward processes. In the case of addition, one has to remember that since 20 units in a lower level are equivalent to one unit in the next level up, 20 units in a lower level are replaced with one dot in the level above it. Figure 3 shows the sum of 8,095 plus 1,166, before and after the grouping process.

This addition example points to rich mathematical experiences in which students can be engaged. Unfortunately, beyond addition, subtraction, and associated algorithms, we do not know whether the Mesoamerican civilizations knew how to multiply, divide, or perform other mathematical algorithms with this vigesimal system. But we do know that the Mayas wrote books on paper just as we do. We know that for 1600 years before Columbus accidentally arrived in the "New World," the Mayas wrote and kept thousands of books in which they recorded their history and cultural achievements.

Tragically, however, the Spanish conquerors and missionaries burned and otherwise destroyed all of the Mayan libraries and archives. Possibly some of those destroyed books contained information on algorithms and other mathematical systems that pre-Columbian societies devised. We know that Mayan astronomers had calculated the cycles of the heavens so exactly that they could predict solar and lunar eclipses to the day, hundreds of years in advance. For example, a Mayan astronomer predicted, some 1200 years in advance, the solar eclipse that occurred on July 11, 1991.

The Mayas knew the synodical revolution of Venus, and some scholars argue that the Mayas also knew the synodical period of Mars and perhaps had parallel knowledge about Mercury, Jupiter, and Saturn. Given their ability to make these calculations as well as to predict celestial phenomena, it is reasonable to believe that they knew how to perform mathematical

algorithms other than addition and subtraction. This belief is rooted in the origins and uses of their vigesimal number systems.

Origins of the Vigesimal Number System

Archaeologists and other scholars maintain that humans first inhabited North America around 30,000 years ago and, in particular, Mexico about 9,000 years later. Groups of hunters and gatherers roamed Mesoamerica for thousands of years before they became sedentary. Jacques Soustelle pins down the advent of agriculture in Mesoamerica at approximately 4000 B.C. However, the organized life that can be called civilization in the region began approximately 5,000 years ago. The social evolution of Mesoamerica can be traced from the hunter-gatherers through the successive civilizations of the Olmecs, Zapotecs, Mayas, Toltecs, Aztecs, and so forth.

The earliest evidence of numerical inscriptions that used positional systems of bars and dots has been traced to the Olmecs in approximately 1,200 B.C. This date is significant, since some 800 years before Aristotle, Plato, and Euclid (whose society did not have a positional number system) began making contributions to Western culture, the Olmecs were already using a positional system. It is worth noting that it was not until 499 A.D. that the Hindu-Arabic number notation using zero in a positional convention first occurred.

The Zapotecs of Oaxaca used the Mesoamerican vigesimal system in their calendars between 900 and 400 B.C. (Between 400 B.C. and 300 B.C., the Izapan culture used the same convention. Later, the Mayas, to whom the vigesimal system is mistakenly attributed, used this system extensively, between 199 A.D. and 900 A.D. The Mayas developed their amazingly complex calendar system and astronomical sciences around this mathematical system hundreds of years before the achievements of Galileo and Copernicus.

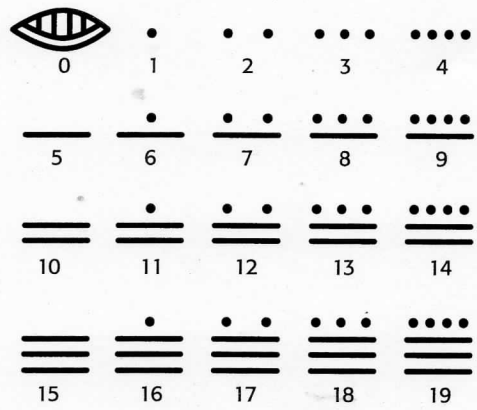

Figure 1: MESOAMERICAN NUMBERS 0–19.

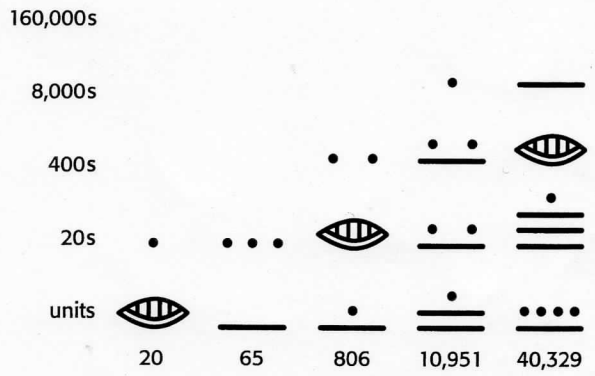

Figure 2: EXAMPLES OF MESOAMERICAN NUMBERS BEYOND 19.

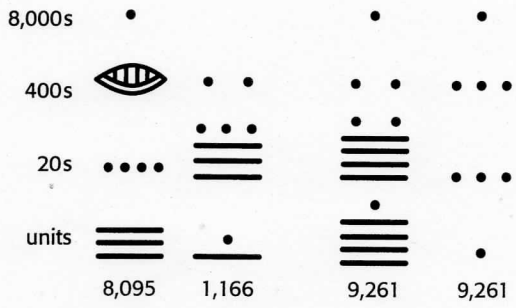

Figure 3: THE SUM OF 8,095 PLUS 1,166, SHOWING THE RESULT BEFORE AND AFTER REGROUPING.

Recommendations to Teachers

The pre-Columbian positional number system can be taught at various educational levels. As we have already seen, it could be included in the elementary school curriculum as a way to deepen how students understand the decimal system. In fact, the Mesoamerican system may be easier for children to grasp than the decimal system: The vigesimal system is visual, and the representation of quantities involves only three symbols — 0, 1, and 5 — and manipulative materials can be adapted to give them physical representation.

For example, Dienes blocks can be adapted to the Mesoamerican base 20 system. Teachers can assign to the smallest blocks the value 1, to the intermediate-sized blocks the value 5, and to the larger blocks or to a group of four intermediate-sized blocks the value 20. Alternatively, in classrooms that do not have Dienes blocks but have manipulative materials of different colors and sizes (rods or chips), different colors or sizes of rods or chips can be used for 1, 5, and 20.

At the middle school and high school levels, discussion of this number system can be included in social studies classes as well as mathematics classes, to broaden student appreciation of the cultural achievements of ancient peoples and the fate of conquered civilizations. Teachers can use this topic to illustrate that impressive mathematical achievements of Mesoamerican civilizations were ignored, devalued, or destroyed as part of the rationale for subjugation and domination. For presentations in social studies courses, a map of Mesoamerica is indispensable and can be obtained from the National Geographic

ACTIVITY BOX

THE HIDDEN GRAIN IN MEAT

BY STEPHANIE KEMPF

One billion of the world's people do not get enough to eat, yet half the grain grown in the world is fed to livestock. Why? To fatten the cattle up for sale to people who can afford to buy meat. Chronically hungry people rarely have the money to buy meat.

Most cattle today do not graze freely on pasture grasses – if they did, their meat would be leaner and healthier. Instead, they are penned up in crowded "feedlots" and given large quantities of grain. The meat from grain-fed cattle is higher in fat.

For every 16 pounds of grain fed to a cow, we get only one pound back in meat on our plates. Producing that pound of meat requires 2,500 gallons of water. In many areas of the world, people do not have access to even a small amount of clean drinking water and must walk miles a day to get it.

DO THE MATH

If your entire class went to McDonald's and each student ate one Quarter-Pounder, how much grain was used to produce the class's lunch? How much water was used?

Explain why you think this is or is not a problem. If it is a problem, what are possible solutions?

From *Finding Solutions to Hunger: Kids Can Make a Difference.* See Resources, page 171.

Society (for additional sources, see Resources, page 173). Teachers can consult other references for more details on the historical origins and uses of this numerical system and for more information on the pre-Columbian cultures who used it.

In mathematics classes at the middle school and high school levels, students can explore interesting mathematics through the Mesoamerican vigesimal system. Teachers can devise exercises comparing the polynomial representation of numbers in our decimal system and the vigesimal system. For example, students can explore interesting mathematics by relating powers of 10 to the value of digits in numerals in the decimal number system and the value of units in the vigesimal system: While the value of a digit in the decimal system is multiplied by a power of 10 that corresponds to the place of the digit of the numeral, the value of the same number of units in the same corresponding place in the vigesimal system is multiplied by a power of 20. This can lead to discussions about powers of 20 as a product of powers of two and powers of 10, to illustrate that the value of units in the vigesimal system increases exponentially faster than the value of the corresponding units in the decimal system. This in turn can serve as a natural introduction to topics related to exponential growth and exponential functions.

Furthermore, in mathematics classes where students are already proficient with the usual algorithm for multiplication in the decimal system (in grades five through 12), teachers can also include classroom activities or homework assignments requiring students to use their creativity when working with the vigesimal system. For instance, the teacher could break the class into groups of three or four students each and ask the groups to generate ideas of how to carry out multiplication in this number system. This idea can be extended to include division as well. These challenging assignments may turn into group projects that can last for an extended period of time.

Given the sophisticated system of ancient Mesoamerican mathematics and the gross underrepresentation of Chicanos in mathematics-based careers in the United States, the comment of Jaime Escalante to his students is indeed sardonic. The legacy of racist discrimination against the cultures and native peoples of Mesoamerica, which resulted from the military conquests and colonization ushered in by Columbus's arrival in the "New World," has continued to this day in the imperialistic practices of U.S. society. It has resulted in an educational system in this country which effectively ignores the rich tradition of excellence in mathematics in the Chicano students' background and fails to instill in young Chicanos a sense of pride in their heritage and a positive self-image.

Despite all this, some modern Chicano mathematicians have made valuable contributions to applied and abstract mathematics — David Sánchez, Richard Griego, Manuel Berriozabal, Richard Tapia, and Bill Velez, to name a few. Their contributions should be used to encourage Chicano students to pursue the exceptional mathematical heritage of their pre-Columbian ancestors. □

This article was adapted from a version which first appeared in *Radical Teacher* magazine. For a link to all references and citations included with the original article, see www.rethinkingschools.org/math.