‘Cultural Mathematics’ in the Oksapmin Curriculum: Continuities and Discontinuities

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Abstract: We report an observational study of school mathematics instruction in Oksapmin, a remote Central Highlands community in Papua New Guinea. As a part of a national initiative, Papua New Guinea is engaged in implementing educational reforms that attempt to create strong links between activities in school and students’ out-of-school lives. We show how reforms have mitigated some of the sharp discontinuities between activities in and out of school though at the same time they have created others. For example, the prior colonial-like system of education that did not allow use of indigenous languages in school classrooms (a discontinuity between in and out of school) has given way to elementary schools in which children are not only encouraged to use their native language in school, they are taught the indigenous mathematics of traditional life. However, in the process of incorporating the traditional mathematics into school instruction, that mathematics is altered in some fundamental ways, as teachers create explicit links to the base 10 English counting system. The transformations of out-of-school practices raise questions about the long-term impact of schooling on out-of-school mathematical practices and traditional ways.

The purpose of this paper is to report an observational study of mathematics instruction in Oksapmin, a remote community in Papua New Guinea (PNG) in which speakers use one of the more than 860 languages that are indigenous to the country. Prior to ongoing educational reforms in PNG, there was a radical discontinuity for Oksapmin children between activities in and outside of school. For example, the official language of instruction for all of the nation’s many grade schools (known as community schools) was English, a language unknown to most parents of school children. The focus of the curriculum was academic – its function was to prepare students to take on leadership roles in the nation, and school curricula included little that was relevant to everyday community life in remote areas like Oksapmin. Further, teachers were not native to Oksapmin, did not speak the indigenous language, and hence could not communicate with parents; teachers tended to stay in their positions in Oksapmin for only 1-year stints, viewing assignments in remote rural areas as undesirable and not adequately compensated. As a result, teachers knew little of local knowledge systems, and they did not know of the Oksapmin’s indigenous 27-body part number system.

The educational reform movement in Papua New Guinea and the availability of schooled Oksapmin people to take on the role of teachers marked a break with the past. With PNG independence in 1975, a movement for vernacular education gradually grew and gained influence with provincial and community governments. In the 1990s, a change in PNG education policy decreed that each community should use their indigenous language for instruction in the first three years of school, gradually bridging to English (for a discussion of PNG education policy, see Litteral, 2000).

In addition to a shift in language policy, educational reforms in Papua New Guinea elementary schools led to changes in targets of instruction. One goal of the new national curriculum is for rural people like the Oksapmin to develop “relevant knowledge, skills and attitudes” (p. 4) and “to respect and improve traditional ways” (p. 6). In keeping with this goal, children are taught “cultural mathematics” in all elementary schools in PNG. Including culturally-based materials in mathematics class is intended by policy makers to serve multiple purposes. As indicated in documents like the National Curriculum Statement, reforms are intended to build on the knowledge that children bring to school, resulting in education that is meaningful to them. Reforms also support children’s acquisition of skills that are relevant to life in their communities, however rural and remote those communities may be (Papua New Guinea Department of Education, 2003); finally, through engaging with

and learning about knowledge systems of their own communities, reforms make efforts to support cultural identities steeped in children's own cultural histories. Though reforms have mitigated some of the striking discontinuities between life in and out of school, new discontinuities have emerged, ones that are more subtle and nuanced. In this paper we examine the changing properties of these discontinuities. To point to these discontinuities, we begin by noting some of Vygotsky's early observations on the characteristics of learning that occurs in and out of school.

As a part of his cultural treatment of learning, Vygotsky (1986) pointed to some important differences between school instruction and learning outside of school (see also Gonzalez, Andrade, Civil, & Moll, 2001, who incorporated some of Vygotsky's ideas in recent analyses of learning in and out of school). In school instruction, concepts are given explicit definitions and presented as a part of conceptual systems. For example, in mathematics class, numbers are a potentially infinite set that can be represented with Hindu-Arabic numerals. Students learn to exploit relationships between numbers by decomposing and recombining numbers. In contrast, in their out-of-school lives, children often create meanings and learn as they solve local, practical problems. Instruction, if it occurs, is often implicit in interactions and local to particular problems.

In this paper, we focus on two related out-of-school practices – indigenous counting systems and currency as a context for arithmetical reasoning and problem solving. We sketch these practices here, and describe the ways in which these practices are transformed when they are imported into mathematics instruction in Oksapmin elementary schools. We examine the shifting relationships in the community between cultural forms (such as the traditional count system and English number words) and the functions they serve as people engage in cultural practices. We will show that both the form and the function of the traditional count system are altered through their inclusion in the elementary school curriculum. We argue that the focus of school mathematics in Oksapmin is to systematize mathematical representations, to create mappings between varied representation systems, and to develop specialized language for mathematics.

The Study

This paper relies on data from a variety of studies undertaken in the summer of 2001 in Oksapmin, Papua New Guinea. Several of these studies are described in detail in (Saxe & Esmonde, in press). We conducted structured interviews with participants ranging in age from 3rd grade students to community elders. Participants also had varied educational backgrounds; many had no formal schooling, while some young adults had completed high school. The interviews were designed to elicit information about counting systems and knowledge of currency terms in Tok Ples (a term for the indigenous language of Oksapmin). A separate study examined collective practices of economic exchange in tradestores.

The bulk of the analysis presented here draws on fieldnotes from observations of elementary school mathematics classes, combined with interview data from our frequent discussions with school teachers. With teacher informants acting as translators, we visited elementary and primary schools and observed 6 mathematics lessons. Our notes focused on mathematical instructional activities in the classroom and student strategies for solving problems. As outsiders to Oksapmin communities and non-speakers of Tok Ples, we enlisted the help of elementary and community school teachers in our research; we conducted structured as well as informal interviews with teachers in which we discussed Oksapmin mathematics and their mathematics lessons.

The Setting

Oksapmin is a small region in the Western Province of Papua New Guinea, with a population of approximately 18,000. At an elevation of about 5000 feet, the Oksapmin people live in a terrain that is mountainous, rugged, densely vegetated and isolated, unconnected by roads to other parts of the country. Traditional subsistence practices that are still practiced today include cultivating taro and sweet potato, keeping pigs, and hunting with bow and arrow for birds and small mammals. People also collect other sources of protein, including varied types of insects, worms, and tadpoles. Most adults residing in Oksapmin have gardens in which they grow a variety of crops for subsistence purposes; excess vegetables are sold in local markets and to vegetable brokers who export many tonnes of vegetables each year to nearby towns.

The first government-run Community School in Oksapmin opened in 1968 (Weeks, 1981). The first teachers were native to other parts of Papua New Guinea, primarily the coastal areas. They were unfamiliar with

Oksapmin language or cultural practices. English was the primary language of instruction, though teachers also used some Tok Pisin in non-instructional contexts. It was not permitted for children to speak Tok Ples while on school grounds (Gearhart, 1980). At the time of our visit in 2001, many aspects of local education had changed. One important shift was that all teachers were native Oksapmin speakers and long-time members of the communities in which they taught.

In 1998, Oksapmin restructured the local education system, in response to large-scale national educational reforms (as described in Papua New Guinea Department of Education, 2003). There are now three levels of schooling in PNG: elementary (grades Prep, E1, and E2) where the language of instruction is the community Tok Ples, bridging to English by the end of E2; primary (grades 3-8) where the language of instruction is primarily English with some Tok Ples; and secondary (grades 9-12), where the language of instruction is English. In the summer of 2001, the first cohort of elementary school students had graduated to attend 3rd grade at the community schools. Up to that point, there had been no official Tok Ples instruction in Oksapmin schools and the curriculum did not include Oksapmin cultural practices. By contrast, under the reforms, elementary schools are charged with teaching a full range of academic subjects in Tok Ples, including 'cultural mathematics.'

Oksapmin communities have undergone rapid change over the last 20 to 30 years; as a result there is great heterogeneity in the mathematical practices of varied groups within the Oksapmin community (Saxe & Esmonde, In press). Our brief sketch provides the contours of traditional and contemporary mathematical practices, but cannot cover all the complexity and variety of the mathematical practices in the region.

Oksapmin Practices involving Counting and Currency

Traditionally, Oksapmin people use a body count system consisting of 27 body parts, as depicted in Figure 1. To count as Oksapmin do, one begins with the thumb on one hand and enumerates 27 places around the upper periphery of the body, ending on the little finger of the opposite hand (Moylan, 1982; Saxe, 1981). To indicate a particular number, one points to the appropriate body part and says the body part name. For example, to indicate the number 12, one points to the ear which is the 12th body part and says the word for ear, *nata*. To count past the 27th body part, one continues up to the wrist, forearm, and on up and around the body. There is no distinction between the name for the 21st body part and the 29th body part; both are called *tan besa* ('other forearm,' indicating the forearm on the opposite side of the body from which the count was initiated).

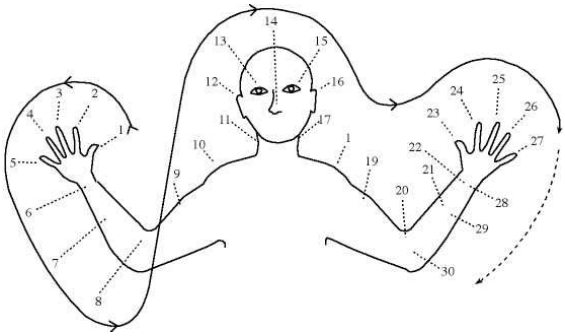

Figure 1. The Oksapmin counting system. In order of occurrence: (1) tip^na, (2) tipnarip, (3) bum rip, (4) h^tdip, (5) h^th^ta, (6) dopa, (7) besa, (8) kir, (9) tow^t, (10) kata, (11) gwer, (12) nata, (13) kina, (14) aruma, (15) tan-kina, (16) tan-nata, (17) tan-gwer, (18) tan-kata, (19) tan-tow^t, (20) tan-kir, (21) tan-besa,(22) tan-dopa, (23) tan-tip^na, (24) tan-tipnarip, (25) tan-bum rip, (26) tan-h^tdip, (27) tan-h^th^ta (Saxe, 1981).

The traditional version of the Tok Ples counting system does not appear to have a base structure. Today, many people use variations of the traditional system that stop at the 20th body part (*tan-kir*), and are endowed with a base structure that facilitates computations with currency (Saxe & Esmonde, in preparation). At the time of our research, several variants of both the 27 body part counting system and the 20 part counting system were widely used. However, structured interviews and informal conversations with 3rd grade schoolchildren revealed that many were unfamiliar with Tok Ples counting beyond the conversational number words used for numbers up to 5.

Over the last half-century, Oksapmin communities have transitioned from barter and subsistence economies to an economic system reliant on currency exchange. Money is a necessity in Oksapmin life today and almost all members of Oksapmin communities are involved with exchange of some form. Within the structure of activity in tradestores and markets, there is great heterogeneity in the kinds of problems and goals constructed by different groups within Oksapmin (Saxe & Esmonde, in press). A variety of cultural forms are used to structure and accomplish mathematical goals in tradestore transactions. These cultural forms include language for number in Tok Ples, Tok Pisin (a pidgin of English, spoken as a second language by many people in PNG), or English, specialized terms for currency in these three languages, written numerals, currency itself, electronic calculators, and record books.

Several characteristics of economic exchange in the Oksapmin context are important to note here. It is possible for transactions to take place without any explicit talk about number or prices; this frequently happens when children make purchases in stores. In addition, many customers are unschooled and therefore unfamiliar with the conventions of written prices. The ability to read price tags is not necessary in order to be a competent participant in tradestore transactions. Finally, not all denominations of PNG currency are used in Oksapmin. All tradestore prices are multiples of 10t. Although 1t, 2t and 5t coins exist in PNG and are used elsewhere, they are rarely found in Oksapmin. In fact, in a series of interviews about currency names in Tok Ples, most adults did not know a Tok Ples name for the 1t, 2t or 5t coins.

School Mathematics in Oksapmin Communities

In this section, we report on the out-of-school knowledge included in elementary classes that we observed in one village school, focusing on transformations of traditional cultural practices as they were accommodated within the structure of school mathematics. We argue that instruction in 'cultural mathematics' resulted in a) systematizing out-of-school mathematical representations, b) creating explicit mappings between varied representational systems, and c) creating a specialized language for mathematics.

Counting and Currency in Elementary School Mathematics

The elementary school is a two-room structure built with indigenous materials, set just off the major path that serves as a road through the Oksapmin region. Children from three local hamlets sit on the dirt floor, facing a blackboard fixed to one wall. Each child has a notebook with about 50 pages that they are to use for all their school subjects. The notebook is intended to last for the entire school year. One area of the room is designated as the 'teacher's corner' and has a table covered with books and papers. In the opposite corner, shelves hold a collection of books – local stories and legends, translated into Tok Ples by Marshall Lawrence, an SIL linguist who had lived in the region for many years. These books, the Bible (which was translated by Marshall Lawrence), and an English/Oksapmin dictionary are the only books to our knowledge ever to be written in Tok Ples. The walls of the classroom hold several educational posters, two of which are mathematical in nature. One poster contains multiplication tables written with Hindu-Arabic numerals. The other lists the first ten body parts of the 27-body part counting system in Tok Ples, along with their matching Hindu-Arabic numerals. There are no representations of Tok Ples counting words beyond the first ten, and no visual representations that indicate the body parts of the counting system.

Tok Ples Counting

In the mathematics lessons that we observed, the body part system was used in varied ways. We saw students and teachers using Tok Ples to count, to describe currency, and to add, subtract, and multiply various objects, including currency. The following fieldnote excerpt describes our first visit to the school, when the E2 children counted in Tok Ples for us.

> The first thing they do when we enter is to count in Tok Ples all around the body up to 27. The children count together, loudly and in unison, up until around 10 (*kata*). After that their unity falls apart. The boys next to me fall silent, occasionally saying a number word. The other children continue saying numbers, but I can't make out what any particular child is saying because everyone seems to be saying different things at once. (fieldnotes July 24, 2001)

This classroom performance demonstrates that the children in the E2 classroom were familiar with Tok Ples numbers up until about 10, after which point their familiarity and proficiency dropped. One possible explanation

is that that the students simply had trouble counting to large numbers. This is probably not the case, since whenever we asked groups of children to count for us in English, they proved their ability to memorize large numbers by counting all the way to 100 loudly, rapidly, and in unison. It is more probable that in this classroom, students used Tok Ples numbers up to ten more frequently than the higher Tok Ples numbers. The classroom poster listing the first ten Tok Ples count words (thumb (1) to shoulder (10), each adjacent to the corresponding Hindu-Arabic numeral)) support this conjecture.

The number ten has no special significance in the traditional Tok Ples number system, but in the elementary school, the number ten was sometimes used in ways analogous to its use in Hindu-Arabic based number systems. This use of the number ten (*kata*) to create a base system for Tok Ples counting is an innovation that creates a link between the traditional counting system and English counting. It may also reflect attempts to systematize the Tok Ples counting system by borrowing the base 10 structure of English counting. For example, in one lesson plan, a teacher asks students to group large numbers of sticks into bundles of 10. In that particular lesson, the teacher expressed 50 as "h^th^t kat-hai," meaning five (pinky) tens (shoulder). This adaptation of the Tok Ples counting system occurred very rarely in our interviews about adult mathematical practices.

Another notable aspect of the children's Tok Ples counting performance was its endpoint, 27 (*tan-h^th^ta*). The traditional count system has 27 body parts, but one can count higher than 27 as demonstrated in Figure 1 above. The modified count system used by many middle-aged adults has 20 body parts, and one counts higher than 20 usually by continuing to the 21st body part (*tan-besa*) or by beginning again at the 1st body part (*tip^na*). This instance of classroom interaction cannot definitively demonstrate the structure of the counting system used there. However, we conducted interviews with 19 3rd grade children who had attended elementary school and all of the children told us that one cannot count higher than 27 using Tok Ples counting.

Creating Mappings between Representational Systems

Much of the elementary school curriculum that we observed focused on creating mappings between different representational systems, including Tok Ples and English words for number, Hindu-Arabic numerals, and pictures representing arithmetic problems. Figure 2 displays several addition problems as the teacher wrote them on the blackboard.

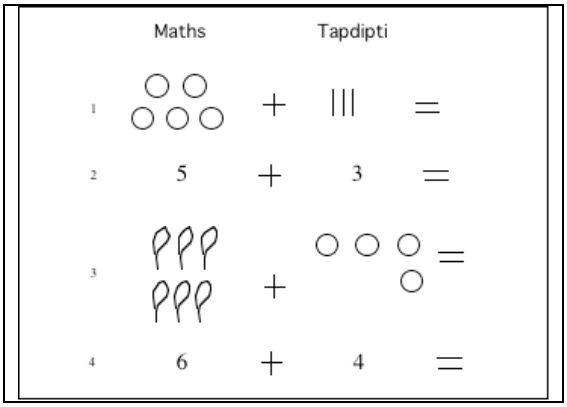

Figure 2. Addition problems in symbols and Hindu-Arabic numerals

The blackboard problems are presented in pictures and in numerals. The teacher proceeded to solve these problems with the students. The picture problems were described using Tok Ples numbers, and solved by counting with the body system. The answers to these Tok Ples problems were expressed with more pictures. For example, for one problem the teacher drew 6 spaces and added them to 4 smiling faces. He drew the solution as a representation of a *bilum* (a string bag) with 6 spades and 4 faces inside of it. The problems written in numerals were described in English, and solved using English counting. The teacher explicitly instructed students in the connections between the four representational systems in use. The connection between English and Tok Ples counting is rarely made in children's out-of-school practices, yet it is a focal point of cultural mathematics instruction.

Later in the lesson, after the teacher had solved several problems with the students, he assigned some arithmetic exercises for them to solve on their own. We observed the strategies that students used to solve these problems. In visits to Oksapmin schools in 1978 and 1980, Saxe (1985) found that school children spontaneously used the body count system to solve school arithmetic problems that were presented in English and Hindu-Arabic numerals. This stands in marked contrast from the strategies used by students in 2001 when presented with English or Tok Ples arithmetic problems. The students we observed often counted in Tok Pisin, used stones as manipulatives, or counted tick marks on their papers to solve the problems. We did not witness any children using body strategies to solve arithmetic problems. It appears that the teacher's efforts to make connections between the representations for number allowed students to solve Tok Ples addition problems using English and pictorial strategies. However, it did not appear that children extended their use of Tok Ples to other representations for number.

Language for Currency

Currency is frequently included in mathematics curricula as a bridge to students' out-of-school experiences and as useful knowledge for children, though school currency tasks can be very different from adults' or children's real world currency practices (Brenner 1998b). We observed one elementary lesson on currency that demonstrated some interesting continuities and discontinuities with community practices. Though the use of indigenous number in currency transactions has a long history in out-of-school practices, in school this relation has taken on a quite different form.

The elementary teacher began the lesson by having students identify the Tok Ples names for all the coins and bills between 1t and K2. He wrote names in Tok Ples for these values, and then wrote the Hindu-Arabic notation for the numerical value of each denomination. See Figure 3 for a blackboard representation that was used to support the lesson. On the blackboard the teacher produced two entries beside 20t because the teacher provided two different names for this coin.

sup tan	1 t
gamintan suptan	2 t
gadep	5 t
wansring	10t
wansring gamintan	20 t
tusring	20 t
gagagsi	50 t
temsi	K1.00
wanpon	K2.00

Figure 3. Blackboard with currency names in Tok Ples

The Tok Ples currency words presented by the teacher represent a complete system of all the denominations from 1t to K2.00. Recall that adults in Oksapmin very rarely if ever used (or saw) the 1t, 2t and 5t coins. Adults generally regard the 10t coin as the basic unit of the currency system. The primacy of the 10t coin is reflected in the term 'gamintan' (meaning 'married coin'), a common name for the 20t coin, referring to the fact that it is equivalent to two (married) 10t coins. In the school system of currency, the 1t coin is the basic unit. Therefore, the term gamintan is used twice – once to describe the 2t coin as equivalent to two 1t coins, and also to describe 20t as two 10t coins. The schoolteacher here represents the Tok Ples words for currency as a coherent system, using currency names that describe relationships between the varied denominations. He also adapts ordinary Tok Ples words, such as 'gamin' for 'married,' and imbues them with specific mathematical meaning.

Addition of Currency

During the currency lesson, students did some addition exercises with coins of different values. For example, they added 'gagasi + gagasi' (50t + 50t) to get 'temsi' (K1). These addition type problems are similar to the types of problems students might encounter as they negotiate a transaction in a tradestore in the local market. However, the presentation of the problem with Hindu-Arabic numerals is an unfamiliar practice for many Oksapmin people – just as it is an unfamiliar practice in U.S. convenience stores to use written notation to figure out how many dollars are equivalent to four quarters. As the teacher and students worked through the

exercises, they were presented in Tok Ples (with no written component) and in English (accompanied by Hindu-Arabic numerals). Once again, creating mappings between the varied representation systems was an explicit focus of instruction.

Although this discussion of currency in elementary school mathematics is based on just one lesson (we observed a number of others and interviewed teachers in some depth about additional lesson plans as well), we can draw some comparisons between currency practices in school and in economic exchange. The use of currency in the elementary classroom during this lesson is both like and unlike out-of-school practices involving currency. Different denominational values are emphasized in school, creating a coherent system built up from the 1t coin; instruction emphasized equivalence relations between the different denominations.

Students also solved arithmetic problems using currency, including some problems involving 1t, 2t and 5t coins. Although these coins are not used in Oksapmin, they are frequently used for purchases in urban centers in PNG. These currency addition exercises may not have been immediately relevant to Oksapmin children, but a familiarity with small denominations would be useful for any Oksapmin person who intended to travel to urban centers far from their small community. The currency addition problems differed from tradestore or market currency problems in other ways; they were presented in a novel form, using Hindu-Arabic numerals. Finally, students received explicit instruction in equivalences although this was not the focus of instruction in everyday practices involving currency.

Continuities and Discontinuities

The apparent discontinuities between Tok Ples counting and arithmetic in and out of school suggest some interesting questions. The education reform documents in PNG state that instruction in elementary schools was intended to (a) build on the knowledge, skills and experience that children bring to school, and (b) preserve and reproduce traditional knowledge. However, the discontinuities that we observed suggest that children were not proficient (and in many cases, not even familiar) with Tok Ples counting or arithmetic before coming to school. Furthermore, the structure of Tok Ples counting that they learned was very different from the traditional system, and would perhaps be unrecognizable to a community elder. Efforts to extend traditional knowledge to new problems (by teaching children arithmetic in Tok Ples) seemed relatively unsuccessful, since students tended to use Tok Pisin or concrete objects to solve the problems, rather than use Tok Ples strategies.

Discussion

In Oksapmin, the relationship between mathematical practices in and outside of school is anything but simple. Throughout the history of schooling in the region, students have experienced discontinuities between community and school cultural practices. In the early English-only schools, many students used the 27 body part system to solve arithmetic problems presented in English and Hindu-Arabic numerals (Saxe, 1985). Despite the fact that children imported their out-of-school practices into the school curriculum, the use of Tok Ples counting in everyday practice declined. This was probably due at least in part to changing historical conditions and the valued status of English for school (Saxe & Esmonde, 2004). By the time the elementary schools opened in Oksapmin, the traditional count system was rarely used in public life. In fact, our interviews with 7th and 8th grade students revealed that many of them could not count in Tok Ples, though they were proficient with English and Tok Pisin counting. The 3rd grade students who had graduated from elementary schools had more knowledge of indigenous counting systems than their older peers.

This demonstrates that the education reforms were somewhat successful in their goals to "respect and improve traditional ways." For many young children, school was their only exposure to traditional number systems and Tok Ples language for currency. This caused a new kind of discontinuity, since schooled versions of out-of-school mathematics were more compatible with 'Western' mathematics, but also more distant from the community's cultural practices, running the risk of seeming irrelevant or even incorrect to older community members. It remains to be seen how the inception of elementary school mathematics will affect students' out-of-school mathematical practices. Our snapshots of elementary school lessons cannot predict the future of Tok Ples counting in Oksapmin. It may be that Tok Ples counting will continue its slow decline, gradually disappearing from community life. On the other hand, the teaching of Tok Ples mathematics in elementary school may revive the use of Tok Ples counting systems, while altering its structure and contributing to the continuing change in Oksapmin mathematics.

Although Oksapmin is a small, isolated community very far from the United States, the lessons learned raise questions for the American context. Currently many researchers suggest that U.S. mathematics instruction should include realistic problems and skills found in students' home communities (Brenner, 1998a; Gonzalez et al., 2001). Such realistic problems would afford students an understanding of the relevance of mathematics to their everyday interests and better engage them in mathematical thinking. The Oksapmin case presents a cautionary note in this regard. Our observations suggest that out-of-school problems and approaches to accomplishing them may inevitably be changed when imported into school contexts, raising questions about a simple application of this instructional practice. Further, there is no guarantee that students will find school versions of their (or their parents') out-of-school practices more engaging or relevant than a traditional curriculum. Indeed, students may not see the connection between school and community versions of what educators view as the same or similar practices. We know little about students' perception of the 'cultural mathematics' that has been imported into American mathematics curricula. Though such curricula are taught with the intention of drawing on and strengthening students' out-of-school knowledge, they should be examined to understand better students' own views about the relevance and value of cultural mathematics.

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