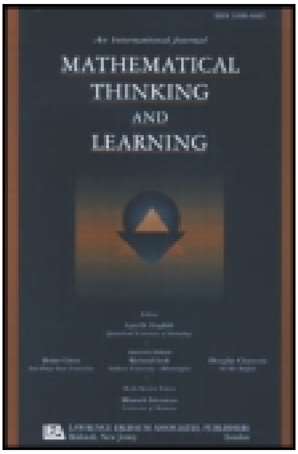

Mathematical Thinking and Learning
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hmtl20

Cultural Development of Mathematical Ideas: Papua New Guinea Studies, by Geoffrey Saxe

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Published online: 17 Apr 2014.

To cite this article: Ellice Ann Forman (2014) Cultural Development of Mathematical Ideas: Papua New Guinea Studies, by Geoffrey Saxe, Mathematical Thinking and Learning, 16:2, 175-180, DOI: 10.1080/10986065.2014.893718

To link to this article: http://dx.doi.org/10.1080/10986065.2014.893718

Mathematical Thinking and Learning, 16: 175–180, 2014

ISSN: 1098-6065 print / 1532-7833 online
DOI: 10.1080/10986065.2014.893718

BOOK REVIEW

Saxe, Geoffrey.[1] *Cultural Development of Mathematical Ideas: Papua New Guinea Studies.* New York, NY: Cambridge University Press, 2012. xxxiii +362 pp. ISBN 9780521761666 $103.00. (Hardcover).

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Cultural anthropologist Clifford Geertz proposed that "small facts speak to large issues" (1973, p. 23). In many ways, Geoffrey Saxe's new book echoes the Geertz quote. By gathering together the many small facts of numerical reasoning practices he has collected over a 30-year period in a community in the Oksapmin region of Papua New Guinea, Saxe has assembled a dynamic documentary report of answers to the question: How are culture and cognition related?

Following the advice of Vygotsky (1986) and others (Cole, 1996), Saxe argues that the appropriate unit of analysis for understanding the intrinsic relationship between culture and cognition is an activity system in the process of change, something that was readily apparent over three decades in the Oksapmin region. His overall approach to research involves the close study of the mathematical practices of individuals with varying amounts of exposure to a market economy or formal schooling. His longitudinal and cross-cohort research designs enable him to outline the impact of cultural processes on cognitive processes and vice-versa. Similar to other cultural psychologists (e.g., Cole & Hatano, 2007), Saxe decides to conceptualize change in three ways: as microgenesis, sociogenesis, and ontogenesis.[2] He defines microgenesis as the short-term shifts that occur when individuals alter notational forms to accomplish new functions; sociogenesis as modifications in collective practices in a community over time; and ontogenesis as transformations of activity over a life-span for an individual.

Before providing a detailed look at the cultural activities of the Oksapmin community, Saxe introduces us to the research literature that has informed his Papua New Guinea work, including his own research in the United States and Brazil. Here you can see how his research questions

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[1]Geoffrey Saxe acknowledges the assistance of Indigo Esmonde on the title page of this book. Some of the material was adapted from previous publications with her (Saxe & Esmonde, 2005a, 2005b). She also assisted in data collection in the field with Saxe in 2001.

[2]The chapter by Cole and Hatano (2007) focused on three kinds of change, phylogeny, cultural history (sociogenesis), and ontogenesis, but they mentioned microgenesis. This book mentions phylogeny at the end but focuses on the other three types of change.

evolved as he discovered the importance of cultural artifacts such as currency in the economic exchanges of child candy sellers in Brazil (Saxe, 1991). In addition, he clarifies how the collective mathematical practices among preschool children and their mothers or among school-aged children with their peers have informed his work in Papua New Guinea (Saxe & Guberman, 1998; Saxe, Guberman, & Gearhart, 1987). He also cites long-term follow-up studies by Greenfield (1999, 2004) that have shown how particular cultural practices such as weaving have been transformed by changes in access to markets and formal schooling in Chiapas, Mexico over a 20-year period.

After preparing us to appreciate his approach to research among the Oksapmin community, Saxe takes us on an imaginary journey similar to the one he undertook in person in the late 1970s. He drops us into the middle of an isolated area of one of the world's largest islands that was cut off from outside influences until 1938 and had experienced limited contact with outsiders in the next 40 years. Here, he met people whose indigenous mathematical practices involved a 27-body part naming system that began with the fingers of the right hand; included the right arm, right shoulder, and the head; and continued to the fingers of the left hand, ending with the left pinky.[3] This cultural mediator (Cole & Hatano, 2007) allowed members of the Oksapmin community to keep track of the ordinal and cardinal characteristics of numbers. He also encountered one native informant, Yangeh, who appeared to modify the body part notational system to achieve the new goals of addition and subtraction required by his work in an Oksapmin trade store. Thus, it seemed as if Yangeh's expertise in exchanging goods for currency provided him with opportunities to introduce innovations, perhaps illustrating the influence of individual improvisations on cultural change (Cole & Hatano, 2007).

When Saxe returned to Papua New Guinea in 1980 and 2001, he decided to further explore his hypothesis based on his earlier observations of Yangeh's innovations in order to understand not only fundamental theoretical questions about culture and cognition but also to document the changes that were occurring in this previously isolated community. During the period from 1978 to 2001, the Oksapmin people were exposed to external cultural influences such as multiple semiotic systems (e.g., Tok Pisin, the lingua franca of Papua New Guinea; English; Hindu-Arabic numerals), a cash economy (modeled after the Australian currency), and formal schooling (modified several times during the colonial and postcolonial periods).

At this point you may be asking: How do these large issues in cultural psychology relate to current concerns in the field of mathematics education? Given the limited space available to answer this question here, I will merely sketch out some topics that interested readers may want to explore further on their own. One topic that receives extensive coverage in this book is the sequence of research questions and methods that Saxe and his colleagues have used in the past three decades. Like many previous anthropologists and cultural psychologists (Cole, 1996; Cole & Hatano, 2007; Greenfield, 1999), Saxe used a variety of field methods (ethnographic description, archival information, cross-cohort sampling, interviews, and experimental tasks) to explore his research questions. He shows us how his methods evolved over time with his research questions and theoretical insights. His honesty about the uncertainties of conducting research in

[3]The figure that he designed to display this counting practice has often appeared in textbooks that discuss cultural differences in indigenous mathematics. In this book, new versions of this figure appear that show how innovations were introduced by individuals or cohorts.

the field and the limitations of his own evidence are refreshing and informative to beginning and experienced researchers.

In addition, Saxe clearly justifies his units of analysis for his explorations of culture and cognition. He defends the use of the genetic method as a way to "parse nature at its joints, given theoretical assumptions about the character of knowledge and knowledge change" (Saxe & Esmonde, 2005b, p. 251). For studies that involve sociogenesis, his unit is cultural activity system (e.g., economic exchange in Oksapmin trade stores or formal schooling). For studies of microgenesis, he focuses on how different cohorts of individuals employ or adapt prior mathematical forms to serve new mathematical functions (e.g., privileging body part names such as elbow [20] when making change using a currency system based on units of 20). For studies that involve ontogenesis, Saxe is able to interview participants (such as Yangeh) repeatedly over time to understand how mathematical representations evolve in an individual's use of old forms to achieve new functions (e.g., from counting to arithmetic operations).[4]

One salient example of the emergent nature of research questions and methods is Saxe's exploration of the notion of "fu." In 1978, this word, when accompanied by a gesture of fists raised seemed to mean a complete count of 27 body parts (e.g., left pinky) or a complete group of plenty. Yet, when Saxe reencountered this word in 2001, its meaning seemed to have changed to indicate that one should double the value of a body part (e.g., double the value of nose [14] to achieve a value of 28). Since the original notional system ended at 27, individual innovations such as this one were required to use numbers larger than 27. Initially Saxe wondered if the two words were related or even if he had misunderstood its earlier meaning. Adding to the mystery was the fact that none of his native informants could recall its earlier meaning.

Saxe continued to pursue this question by asking three informants from different age groups to describe the use of fu. Their accounts varied from values of 27 (left pinky) [from an elder] to 20 (left elbow) or 27 [from an older adult] to 20 [from a younger adult]. After extending his sample to schooled and unschooled adults as well as schooled adolescents, he found a variety of meanings for fu, including many people who did not recognize the word at all (especially among those who had attended school). He also found that some associated fu with a complete group of plenty; others identified it with a unit of currency (20, which was originally worth 20 Australian shillings); and others with the doubling of the numerical value of a body part. Thus, uncovering of the meaning and function of fu enabled Saxe to illustrate the variability of cultural mediation over time and across individuals and cohorts while exploring the use of important notational systems (body parts or coins for enumeration or arithmetic operations, including multiplication).

Moving to the context of formal schooling, other mysteries emerged. When Saxe and Maryl Gearhart studied community schools in 1980, they found that the teachers were using English and Hindu-Arabic numerals to teach arithmetic operations of addition and subtraction to children. Their photos of these classrooms (including the one that appears on the cover of the book), show some children counting by pointing to or moving parts of their bodies during a mathematics lesson, perhaps in order to translate this alien semiotic system into something familiar. They found out that the teachers had been imported from other parts of Papua New Guinea and neither spoke the Oksapmin language nor were aware of the indigenous body part notional system.

[4]See Hatano (2005) for a critical review of these intersecting genetic analyses and Saxe and Esmonde (2005b) for a response.

In order to further explore what the school children understood about mathematical operations, Saxe and Gearhart designed tasks that required children to do addition and subtraction problems containing cardinal numbers that ranged from 3 to 43. They predicted that operations with numbers larger than 27 would offer a distinct challenge to students who relied on the indigenous notational system. They documented the use of invented strategies (double-enumeration or body-part substitution) and hybrid forms (e.g., combinations of Western numeration and indigenous notations), particularly for the problems involving the largest numbers. In addition, they found that the younger children used the body part notation overtly in their calculations whereas the older children reported that they had used it covertly. Many of the results of their studies with school students were similar to their findings with adults who were involved with economic exchange. One of these findings (the transformation of physical actions into mental actions) has also been reported in studies of the mental operations of experts in other fields (e.g., abacus experts) (Cole & Hatano, 2007).

There was a period of school reform between 1980 and 2001. When Saxe returned to the same community school he had visited before, he found that the teachers were using three languages to instruct (Oksapmin, Tok Pisin, and English) and also used body part notations, Hindu-Arabic symbols, and coins in their mathematics lessons. These teachers had come from the local community and were following a curriculum that explicitly required them to build bridges from the local languages and practices to Western languages and computational practices.[5] They also attended many community activities such as local churches or athletic games.

This apparently positive sign of teachers' growing awareness of their students' background knowledge also contained a few negative features. For example, Saxe found out that the educational administrator responsible for overseeing several community schools described an indigenous body part notational system that differed from the one Saxe had documented in his earlier work. That is, the administrator thought that the counting was symmetrical: from right thumb (1) to left thumb (27) instead of from right thumb (1) to left pinky (27). This symmetric version was also the one used by the two classroom teachers that Saxe observed. In addition, he found that the use of the body part system among school children was quite limited, since most arithmetic operations were done using Hindu-Arabic algorithms (e.g., regrouping in subtraction problems) and that English and Tok Pisin were spoken much more than Oksapmin. Thus, educational reform had produced unintended consequences for the children and their teachers. Instead of creating bridges between Oksapmin and Western forms of mathematical operations, it was a likely cause of the distortion or disappearance of indigenous forms. In addition, the variable use of the body part system in 1980 (including invented and hybrid strategies) was being replaced by a common set of Western mathematical algorithms in 2001.

In conclusion, what does a book like this contribute to the field of mathematics education? One important contribution is its relationship to the evolution of learning theories in the past 30 years. Commenting on an earlier publication by Saxe and Esmonde (2005a), Sfard (2005) argued that their investigation of fu shows us how far Saxe has come in his own theoretical and empirical development since the earliest studies of Oksapmin body part counting. From his beginnings as someone strongly influenced by universalistic developmental theories like Piaget's, Sfard claimed

[5]As cash employment increased in the area in 2001, more families could afford to send their children to school. This unfortunately resulted in overcrowding in the community school. The third-grade teacher was responsible for 91 students who were taught in two different half-day sessions.

that Saxe has shifted to someone who is now captivated by changes in cultural notations over time and among cohorts of people with differing degrees of exposure to collective practices such as currency transactions or formal schooling.[6] This is a radical change from individualistic and universalistic views of learning to more situated, semiotic, and social perspectives. Clearly this transformation of learning theories has implications for how we study mathematical reasoning inside and outside of school settings (e.g., Boaler, 2000).

Another contribution is the transformation of concepts of "culture" from essentialist notions of homogeneous groups of people sharing a common, coherent set of characteristics (e.g., stereotypes) to a multifaceted and emergent narrative of variability and change due to the reciprocal influences of individual and collective practices and the affordances and constraints of cultural mediators. As we saw in the Oksapmin community schools in 2001, attempts to build new mathematical knowledge on students' prior knowledge can achieve the opposite results, particularly when those attempts are based on limited or erroneous understanding of the indigenous practices. This can also occur when students and their families are aware that employment opportunities in a cash economy require mastery of more widely accepted semiotic resources (e.g., English or Tok Pisin; Hindu-Arabic numerals and algorithms) or feel that using indigenous practices makes them look incompetent. As the field of mathematics education tries to address the disparate needs and interests of a multicultural community of learners, it becomes necessary for us to abandon essentialist notions of culture for multifaceted and dynamic perspectives on students' prior and evolving understanding of mathematical practices (Gutiérrez, Baquedano-Lopez, & Tejeda, 1999; Nasir & Cobb, 2007).

At the end of this book, Saxe returns us to the Geertz quote at the beginning of this review by suggesting that this culmination of 30 years of field work in Oksapmin mathematics makes three distinct contributions to the literature: thick description of a vanishing cultural community, little theory, and big theory. His detailed accounts of their mathematical activities such as making charge in trade stores or counting, adding, subtracting, and doubling numbers, inside and outside of formal schools, make substantial contributions to the research literature on culture and cognition. His theoretical interpretations of the value of his evidence for theorizing about the mechanisms of development are equally generative. "I took the Oksapmin world as a case in which shifting collective practices involving number provided a remarkable window into the interplay between microgenetic, sociogenetic, and ontogenetic processes and the shifting collective practice of everyday life" (p. 330). Although I agree with this quote, I would like to add that this important book provides a window into the professional career of a remarkable researcher and scholar.

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[6]Interested readers will notice that the debate between Sfard and Saxe reported in this special issue in 2005 is continued in this book's preface.

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