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Improving Research on Mathematics Learning and Teaching in Rural Contexts

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An adequate research base for mathematics learning and teaching in rural areas does not exist. According to Silver (2001), mathematics education research has virtually ignored rural context, even though approximately one third of the nation's population lives in rural areas. Mathematics education and rural education researchers seem to have little understanding of each other's work. In response to this disconnect, I describe ethnomathematics in mathematics education and place-based pedagogy in rural education and, in turn, discuss how research in place-based pedagogy can benefit from research methodologies in ethnomathematics. Specifically, I offer (a) an overview and analysis of current issues regarding mathematics in rural contexts; (b) a broader view of the role of mathematics in rural contexts and in place-based pedagogy; and (c) recommendations for much needed collaboration in research and practice in mathematics education in rural contexts.

Issues Regarding Mathematics Education in Rural Contexts

At the heart of teaching and learning mathematics in rural contexts are beliefs about schooling and the nature of mathematics. How do rural educators and mathematics educators view the roles of schooling in general and mathematics in particular? The discussion that follows will help lay the groundwork for improving research in mathematics education in rural contexts.

Roles of Schooling

Mathematics education has undergone several iterations of national reform in the past half century. These varied reforms have been driven by presumed national priorities: the need to fuel the scientific and economic engines of the nation and to be competitive globally.

In the U.S., among the responses to the launching of Sputnik was the enhancement of the national capacity in mathematics and science. School mathematics curricula, developed largely by mathematicians and labeled "new math," became suddenly more rigorous. This movement waned quickly, however, partly through opposition from parents and teachers. Public dissatisfaction, teachers' hesitancy, and dubious standardized assessment results ensured its demise (Fey & Graeber, 2003). "Back to Basics" subsequently emerged in the 1970s, persisting through the mid-1980s. This movement had a different view of rigor, one grounded in a focus on proficient calculations in arithmetic and algebra, and with heavy reliance on memorization. Teachers used traditional teaching practices in which they told and showed students how to do school mathematics.

Three documents in the early 1980s—*An Agenda for Action* (National Council of Teachers of Mathematics [NCTM], 1980), *A Nation at Risk* (National Commission for Excellence in Education, 1983), and *Educating Americans for the Twenty-first Century* (National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983)—raised concern again about the nation's capacity in mathematics (Fey & Graeber, 2003). In 1989, the NCTM published its landmark document, *Curriculum and Evaluation Standards for School Mathematics*, which envisioned a school mathematics curriculum and pedagogy intended to enable all students to succeed in mathematics. Soon after these standards were released, President Bush met with state governors to draft six (later, nine) national goals for education. One of these goals focused on mathematics and science, optimistically asserting that by the year 2000, U.S. students would lead the world in mathematics and science. A national report from the National Commis-

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sion on Mathematics and Science Teaching for the 21st Century (2000), led by former astronaut and senator John Glenn, asserted that knowing mathematics was important because of “the rapid pace of change in both the increasingly interdependent global economy and in the American workforce” (p. 7).

Recently revised national standards in mathematics, developed by the NCTM (2000), emphasize the mathematical knowledge, skills, and reasoning required to be productive citizens in the contemporary world. Finally, the No Child Left Behind legislation stresses reading and mathematics as essential parts of the economic infrastructure.

With these national movements and trends have come a variety of strategies for altering mathematics teaching and learning in U.S. schools. Not all have represented improvements, but each has influenced the research that has been conducted in mathematics education.

Kannapel and DeYoung (1999) concluded from their analysis of research in rural education that rural areas have been ignored by national movements. Presumably, this would include movements in mathematics education as well. On the one hand, national and state leaders set standards for all schools and students within their jurisdiction. These standards represent authoritative claims about what is necessary to build a mathematically literate workforce and a strong national economic infrastructure. Accountability systems sanction implementation of the standards, and educators, including rural teachers and administrators, must address them. On the other hand, local communities exert powerful, but largely informal, influences on schools.

What constitutes local influence? Some things are known. The social norms of rural areas value place, community, and family over other more distant national priorities. Rural families tend to adopt more traditional values like hard work, discipline, and relationships (Haas & Nachtigal, 1998; Nachtigal, 1982; Seal & Harmon, 1995). Rural residents tend to select low paying jobs close to family and friends over high paying jobs some distance away (DeYoung, 1995; Seal & Harmon, 1995). Communities tend to construe schools as their centers (DeYoung & Lawrence, 1995; Herzog & Pittman, 1995, Nachtigal, 1982; Stern, 1994). Rural schools tend to be smaller than urban schools, despite 20 years of consolidation efforts (Sher, 1983; Stern, 1994). Rural adolescents often are conflicted about career aspirations because the pursuit of higher education takes them out of the community (Campbell & Silver, 1999). This conflict may be greatest among those most at-risk for departure, such as the academically talented (see Howley, Harmon, & Leopold, 1996).

Of course, rural teachers are often caught in the middle of these conflicting priorities (Gibbs & Howley, 2000; Kannapel, 2000). They must teach mathematics deemed important by state or national standards, and they must continue to live among neighbors who may regard these standards as less important than community needs. Concerned about these conflicting priorities, the Annenburg Rural Challenge (1999) issued a policy statement regarding educational standards in rural areas. The Rural Challenge advocated that (a) rural schools must set high academic standards for their students, (b) academic standards should originate with communities, and (c) academic standards should address context and learning conditions along with subject area content.

Access to Challenging Mathematics That Matters

Despite several national reform movements in mathematics education, students rarely have access to mathematics that matters. That is, the mathematics that many students learn is connected to neither them nor their community. Mathematics teaching often fails to challenge students or to provide them with the necessary knowledge for important life skills.

The warrant for such claims is strong. Stigler and Hiebert (1999) studied videos of eighth-grade mathematics lessons from the United States, Germany, and Japan as part of the Trends in Mathematics and Science Study (TIMSS). Their analysis revealed that, when compared to German and Japanese mathematics lessons, U. S. lessons addressed mathematics at a much lower level, focused more on learning terms and practicing procedures, developed understanding of mathematics concepts less often, were more fragmented and less cohesive, made fewer connections within lessons, were rated considerably less rigorous in challenging students, and engaged student thinking less often.

More recently, Weiss, Pasley, Smith, Banilower, & Heck (2003) analyzed 364 mathematics lessons of K-12 teachers across the United States. They reported that “fewer than 1 in 5 mathematics lessons are strong in intellectual rigor; include teacher questioning that is likely to enhance student conceptual understanding; and provide sense-making appropriate for the needs of the students and the purpose of the lesson” (p. 2). They found that instruction was highly teacher-centered and rarely provided opportunities for students to think or reason mathematically. These two studies reveal a disconnect between the mathematics students learn in school and the mathematics that students might need outside school, a disconnect sharpest for reasons mentioned earlier (e.g., Kannapel & DeYoung, 1991).

Some evidence suggests that students from impoverished communities suffer most from this disconnect. Haberman (1991) reported that urban and rural teachers in high poverty areas have adopted a “pedagogy of poverty,” where teachers presume incapacity and fail to challenge students mathematically. Curriculum is “dumbed down” to cover basic mathematics, such as arithmetic and simple algebra. Ironically, in rural communities of high poverty, where a need to connect mathematics to culture and community is perhaps greatest, teachers are mostly likely to fail in making local connections.

Mathematics teacher quality is an issue in rural areas as well. A survey of 896 rural school district superintendents revealed that small school districts employed fewer teachers who met "highly qualified" criteria, and had greater difficulty in attracting and retaining teachers than superintendents in larger districts (Schwartzbeck, Redfield, Morris, & Hammer, 2003). The survey indicated that the three primary challenges to attracting qualified teachers in rural areas included low salary, social isolation, and geographic isolation. Worse still, the issue of poor quality is more pressing in mathematics because of the severe shortages of certified mathematics teachers (American Association for Employment in Education, 1999; Darling-Hammond, Hudson, & Kirby, 1989).

The Role of Mathematics in Rural Contexts

Recent trends in mathematics education offer some hope for changing the role of mathematics in rural contexts. In particular, the study of ethnomathematics can help educators connect school mathematics to rural students and their communities. In this section, I describe ethnomathematics and analyze its potential impacts on the learning and teaching of mathematics.

Ethnomathematics

In the early 1980s, mathematicians and mathematics educators began to explore mathematics' connections to culture and culture's effects on mathematics teaching and learning. The Brazilian mathematician Ubitarian D'Ambrosio (1984) coined the term ethnomathematics. "Ethnomathematics," he said, "is the way different cultural groups mathematise (count, measure, relate, classify, and infer)" (p. 2). According to D'Ambrosio, the prefix ethno describes "all of the ingredients that make up the cultural identity of a group—language, codes, values, jargon, beliefs, food and dress, habits, and physical traits." The term mathematics describes "a broad view of mathematics which includes ciphering, arithmetic, classifying, ordering, inferring, and modeling" (pp. 2-3). Thus, ethnomathematics examines the ways varied cultures develop and use mathematics.

At about the same time, Paulus Gerdes of Mozambique, Marcia Ascher of the United States, and Alan Bishop of the United Kingdom conducted research on the effects of culture on mathematics (Barton, 1996). These writers elaborated on the interplay between culture and mathematics, and their work stimulated additional empirical research. Vithal and Skovsmose (1997), after a thorough analysis of this work, offered a definition that attempts to capture the varied dimensions of ethnomathematics:

> Ethnomathematics refers to a cluster of ideas concerning the history of mathematics, the cultural roots of mathematics, the implicit mathematics in everyday settings, and mathematics education. (p. 133)

The cultural nature of mathematics. At the heart of beliefs about the cultural nature of mathematics is the nature of mathematics itself. According to Dossey (1992), even mathematicians cannot agree on the nature of mathematics. One primary issue is whether mathematics is external or internal to the person. For example, some believe that mathematics is a human invention; others believe that mathematics is embedded in nature and must be discovered. Alan Bishop (1983, 1988a, 1988b), one of the earliest writers about culture and mathematics, believed the former—that mathematics is a cultural product that has developed as a result of various activities within a culture. That is, each culture has invented its own mathematics. The "cultural products" that Bishop observed to be common to all cultures included counting, locating, measuring, designing, playing, and explaining.

Research on mathematics in other cultures has included extensive anthropological work on the mathematical thought of different peoples throughout the world. This research has focused on the intuitive mathematical thinking that has developed in largely undereducated cultures, such as the mathematical development of native peoples of Australia (Harris, 1991), Liberia (Gay & Cole, 1967), North America (Ascher, 1991), the Pacific Islands (Kyselka, 1981), and Africa (Gerdes, 1991a, 1991b; Zaslavsky, 1973). This work provides convincing evidence that mathematical thought is developed intuitively and apart from formal schooling.

Another connection between culture and mathematics involves the evolution of mathematics. That is, what is the cultural history of mathematics that formed mathematics as we know it today? Examples of this type of historical analysis are found in Fang and Takayama (1975), Joseph (1991), Kline (1953), and Swetz (1987). The politics of mathematics represents yet another important cultural connection (Barton, 1996). The relevant question here is, "How has mathematics over time shaped society in broader political ways?" Bishop's (1990) essay on the influence of western mathematics on society is an exemplar in this regard.

The cultural nature of mathematics education. Culture and mathematics education have strong connections. Cultural institutions and values affect the nature of mathematics teaching, learning, and curriculum. Conversely, what is taught and learned in schools can influence culture and communities.

Many writers have commented on teaching and learning mathematics in culturally specific contexts. Two themes predominate: (a) using relevant cultural examples from students' lives and (b) exposing students to a variety of cultural contexts (multiculturalism). Robert Moses' Algebra Project, which began in Mississippi in 1982 and has been instituted in urban and rural communities across the U.S., provides one of the most compelling and far-reaching examples of this type of ethnomathematics activity (Moses & Cobb, 2002). Other examples of the first theme include the work of Nelson-Barber and Estrin (1995) and Bradley (1984), who argued for the revision of mathematics teaching and curricula to capture the traditions and culture of Native Americans; Gerdes (1988, 2001), who offered suggestions for using African art and games to teach mathematics in elementary classrooms; Malloy (1997), who proposed activities for improving mathematics instruction for African American students; and Flores (1997), who suggested cultural activities and materials for Hispanic students. Regarding the second theme, Zaslavsky's (1991, 1998) suggestions for integrating ethnomathematics in middle school and elementary classrooms, Karp's (1994) use of multicultural children's literature for teaching mathematics, Dolinko's (1997) use of national flags in instruction, Yao's (1984) suggestions for multicultural teaching, and Presmeg's (1998) suggestions for multicultural mathematics teacher education programs all provide examples of engaging students in a variety of multicultural mathematics activities.

The situated-cognition literature provides a different slant on culture's influence on mathematics education. Researchers pursing this line of inquiry study the mathematics learned by students and adults in order to perform life skills as opposed to the formalized, codified mathematics learned in school. Barton (1996) offered several examples of this type of research: Saxe's (1988) study of Brazilian candy vendors; Carraher, Carraher, & Schliemann's (1985) work with illiterate Brazilians; Lancy's (1983) work with the Kewa of Papua New Guinea; Schribner's (1984) study of dairy farmers in the United States; Lave's (1988) study of American shoppers; and Masingila's (1992) study of carpet layers.

Ethnomathematics researchers have studied societal effects on mathematics education. Barton (1996) used Gerdes's analyses of the mathematics education reformation in Mozambique (Gerdes, 1985) to illustrate mathematics education's influence on politics and society. Vithal and Skovsmose (1997) provide a similar analysis of the role of mathematics education in social changes within South Africa. Based on the critical education theory of Freire (1992, 1994), Frankenstein (1997) and Gutstein (2003) described a critical mathematics pedagogy and curriculum to help students understand how mathematics serves as a mechanism that creates and reveals the deployment of power and oppression. Stanic's (1989) call for the elimination of cultural discontinuity and social inequality in classrooms through mathematics instruction addresses this issue on a more local level.

The extensive work in ethnomathematics globally has been conducted in a variety of contexts—from the tribes of Africa to inner city children in Brazil to dairy farmers in Wisconsin. Many of these contexts are rural, but oddly enough, "ruralness" is rarely considered as a salient influence. These studies focused exclusively on differences among the wealthy and impoverished, the powerful and the oppressed, or the majority and the ethnic minority. Locality is roundly ignored by this literature. In fact, only Bishop (1994) even recommended rural as a potential construct for use in ethnomathematics investigations. Rural places, with their unique and diverse local cultures, would nonetheless seem to have high potential to disclose interesting and useful insights about connections between mathematics, mathematics education, and culture.

The Role of Mathematics in Place-Based Pedagogy

In the past several decades, rural educators, with strong support from the Rural and Community Trust, have adopted a pedagogical philosophy that connects instructional practices and curricula to local communities. Arising from the philosophies of John Dewey and Maria Montessori as well as the work of Eliot Wigginton and the Foxfire, place-based pedagogy has been revitalized in today's rural schools (Haas & Nachtigal, 1998; Lewicki, 2000; Smith, 2002; Theobald, 1997). The approach recasts the role of subject areas in rural schools as helping to explain, understand, and improve local communities and places.

The literature on place-based pedagogy reveals a scattering of methodologies and activities to date. Smith (2002) has perhaps provided the most accessible and practical synthesis describing place-based pedagogy. He identified five thematic patterns: (a) cultural studies that engage students in learning about their local culture and history; (b) nature studies that focus students on local natural resources; (c) real-world problem solving that involves students in solving community and local problems; (d) internships and entrepreneurial opportunities that engage students in building the economic base of their communities; and (e) induction into community processes where students are engaged in community decision making. More recently, Gruenewald (2003) argued that place-based pedagogy ought to serve an additional role—critical pedagogy as proposed by Freire (1983) and his followers. Critical pedagogy is based on the belief that education should help students engage in the struggle for social justice, particularly in their own lives. Gruenewald (2003), after a review of the literature on place-based pedagogy, notes that its proponents rarely even mention exploring issues of social injustice. He argues that, since both pedagogies focus on improving communities and place, critical pedagogy ought to be a significant theme within place-based pedagogy.

The literature on place-based pedagogy provides several examples of ways in which mathematics has been used in classroom activities. For example, Smith (2002) reported that administrators, teachers, and parents in Fairbanks (AK) reshaped their mathematics and science curriculum around the preservation of nearby natural resources, and that a calculus class in Seaside (OR) helped local safety officials determine the effects of tides on Seaside's buildings. Lewicki (2000) claims that high school students improved standardized mathematics scores through work on place-based projects that required them to gather data about a local river. Students in Big Springs (NE) used measurement and scaling to build clay replicas of buildings in their town (Kroger, 2000). Junior high students in Tillamook (OR) developed a mathematical model to help local loggers identify the number of trees and stumps in logged areas (Loveland, 2002).

In most of the place-based applications found in the literature, mathematics serves primarily as a tool to solve problems or understand community circumstances. As expected, the applications are often developed by teachers in a particular locale. While these applications provide excellent connections to place, they typically provide a limited view of mathematics. When individual teachers build their instruction around applications, they risk delivering an incoherent and less rigorous curriculum. Richer applications are ignored in favor of consumer-driven mathematics that is based on simple applications of arithmetic, measurement, algebra, or statistics. While students may appreciate the utility of mathematics through these applications, they do not always engage in mathematics as an axiomatic system, as a way of thinking, or as a way of communicating. As with any mathematics lesson or activity, the mathematics embedded in place-based activities is constrained by teachers' knowledge of mathematics. Teachers simply cannot "see" mathematics that they do not know, even though it exists within real applications. In a place-based environment, student learning can be limited only to the mathematics seen by their teachers, just like the connections to place are limited by the teachers' understanding of place.

Notable contextual curricula have been developed by teams of mathematics educators, mathematicians, and teachers; these provide a broader view of mathematics in a variety of contexts. Examples are Integrated Mathematics Project and Core Plus (high school), Connected Mathematics Project and Mathematics in Context (middle level), and Investigations in Number, Data, and Space (elementary level). Place-based pedagogy can benefit from similar collaborative efforts among rural teachers, rural educators, mathematicians, and mathematics educators, as I suggest next.

Need for Collaboration

Collaboration among mathematicians, mathematics educators, and rural educators should occur on at least two levels: (a) broadening the nature and goals of place-based pedagogy and (b) conceptualizing and conducting research on place-based pedagogy.

Broadening the Role of Place-Based Pedagogy

These collaborations have the potential to broaden the goals of place-based pedagogy, particularly with regard to mathematics. A comparative analysis of ethnomathematics and place-based pedagogy reveals that ethnomathematics makes broader connections between mathematics and culture than do the mathematics applications thus far suggested for place-based pedagogy. In fact, place-based pedagogy, as characterized by Smith (2002) and Gruenewald (2003) and as illustrated in the literature, addresses only a few of Barton's (1996) dimensions of ethnomathematics. Most place-based pedagogy clearly falls in the mathematics education domain, defining mathematics as a cultural tool for describing rural places and solving rural problems. As reported by Smith (2002), several mathematical applications of place-based pedagogy do engage students in projects that help them better understand the circumstances of their community and local environment; others have students use mathematics to solve local problems. While this role of mathematics is critically important and appropriate for rural communities, it fails to take full advantage of mathematics' interaction with culture as illustrated in the ethnomathematics literature. This limited role for mathematics is understandable given that place-based pedagogy arose from a grassroots movement by educators who sought to connect schooling to the lives of students. The connections themselves dictate the use of mathematics, with little consideration of the broader nature of mathematics itself.

An enhanced place-based pedagogy that focuses on descriptions of indigenous mathematics concepts, historical development of mathematical ideas, and uses of mathematics to explore the sociopolitical climate of the region can not only broaden students' view of the nature, role, and utility of mathematics, but it can enhance their understanding and appreciation of their place. It can help them realize that mathematics is an artifact of their culture and has a clear role in their place. If place-based mathematics pedagogy is broadened to Barton's characterization of ethnomathematics, then new forms of mathematics classroom activities will emerge for rural teachers and students. New opportunities for research in classrooms, schools, and communities also will arise.

Conceptualizing and Conducting Research on Place-Based Pedagogy

As mentioned earlier, the scant research on place-based pedagogy offers little empirical evidence with regard to its effect on students, schools, and communities. Expanding the nature of mathematical applications of place-based pedagogy will stimulate a variety of research questions and approaches to research. If place-based pedagogy is to become a viable cultural tool, a broader range of research must be undertaken. Empirical research on the goals, nature, implementation, and impact of place-based pedagogy is needed. In this regard, ethnomathematics research that builds stronger bridges between mathematics and culture in rural contexts can expand the definition and goals of place-based pedagogy. The sections that follow offer suggestions for ethnomathematics research in rural contexts and for expanded research on place-based pedagogy. I use Appalachia to illustrate particularities related to place.

Ethnomathematics research in rural contexts. Barton (1996) identified four types of empirical methodologies that characterize ethnomathematics research: descriptive, archaeological, mathematizing, and analytical. In the following sections, examples of these types of research in the context of mathematics education in Appalachia will be offered.

Descriptive ethnomathematics research and activities reveal how mathematics is used in a particular culture. They describe how members of a culture intuitively use mathematics in everyday life. Descriptive ethnomathematics research in Appalachia culture might focus on: (a) how mathematics is used to reclaim land ravaged through mining or logging; (b) how mathematics is used in local businesses and industry; or (c) how mathematics can be used to explain why a local lake, river, or stream is changing. Much of the current work in place-based pedagogy seems to fall in this category.

Descriptive research includes studies that investigate community, parent, teacher, and student beliefs about mathematics as well as beliefs about mathematics teaching and learning. Specific studies might pursue (a) what Appalachian community members believe and feel about mathematics as a school subject; (b) where Appalachian high school students capable in mathematics go and what they do; or (c) what roles mathematics teachers play in Appalachian schools and communities. Until educators understand perceptions and roles of mathematics teaching and learning in particular rural areas, strategies for helping teachers, administrators, and policymakers connect mathematics education to communities run the risk of being off target.

Archeological ethnomathematics research is historical in nature and describes how mathematics has been used to create cultural artifacts (Barton, 1996). Thus, ethnomathematics research reveals the importance of mathematics in developing local culture. Appalachian examples include (a) how Appalachian women used concepts of geometry and measurement to design and create quilts, (b) how early Appalachian settlers used mathematics to map out and clear land for communities and farmland in a mountainous region, or (c) how Appalachian musicians used mathematics to create indigenous musical instruments. In these instances, individuals using the mathematics were often not aware that they were using sophisticated or formal mathematical ideas. These types of research and activities are largely unexplored in the current mathematics place-based work.

Mathematizing ethnomathematics research involves connecting the informal mathematics developed in a culture to formal mathematical ideas. This research is similar to archeological research; however, the focus is on current, rather than past, uses of mathematics in the community. For example, Appalachian quilt designs reflect formal geometric concepts like symmetry, similarity, congruence, transformations, rotations, reflections, and fractals. In fact, these geometry concepts have been explored through a variety of K-12 geometry lessons centered on quilt patterns (Moyer, 2001; Paznokas, 2003; Westegaard, 1998; Whitman, 1991). Other Appalachian examples include examining how local engineers control water flow in creeks and rivers or studying the economic impact of a particular industry (e.g., coal, timber, manufacturing, technology) on the community. Researchers would study teachers' strategies for transforming local uses of mathematics into classroom mathematics activities or tasks.

Analytic ethnomathematics research and activities involve using mathematics to investigate or explain existing cultural circumstances. Gutstein (2003) used analytical research to study how Latino middle school students in Chicago developed a sense of social justice and sociopolitical consciousness. Over 2 years, he asked students to work on what he called "real world" projects. These projects required mathematics found in a middle school curriculum to explore and understand local social issues. The projects focused on issues like abortion, teen pregnancy, homosexual marriage, race discrimination, power, and justice. Comparable analytical activities and research in Appalachian mathematics classrooms might focus on land ownership patterns, distribution of poverty and wealth, influences on local economy, environmental issues, family structures and connections, or the economics of politics. This role of mathematics has been largely untapped in the current place-based pedagogy literature. However, Gruenewald (2003) made a compelling case for expanding the focus of current place-based activities to a focus on critical pedagogy.

Expanded research on place-based pedagogy. Place-based mathematics pedagogy appears on the surface and in theory to have many strengths, but the goals, nature, implementation, and benefits of place-based pedagogy have not been explored. The role of mathematics in place-based pedagogy appears largely as a tool to understand and solve community problems. Another important role for mathematics rarely used in place-based pedagogy is to serve as a language for describing our world. This role can be developed in Appalachian classrooms by helping students understand important geometry concepts through analyses of local quilts, art, and crafts. Mathematics also can be viewed as a way of thinking through a situation logically. To fulfill this role, Appalachian teachers can ask students to use deductive or inductive reasoning to explore how particular phenomena, like floods, landslides, or forest fires, affect their communities physically, socially, or economically. In these contexts, researchers would describe the effects that these classroom explorations have on students' understanding of mathematics, attitudes toward mathematics, and appreciation of their local culture.

Research on the nature of place-based mathematics pedagogy is needed. For example, it is not clear from the existing literature what the necessary and sufficient conditions for place-based activities are. Most mathematics applications of place-based pedagogy in the literature are conducted through project-based activities that engage groups or classes of students in solving local problems or exploring local issues. Two general issues—depth and authenticity—arise with regard to the nature of place-based pedagogy. To take an extreme, depth becomes an issue when teachers simply amend traditional textbook word problems to include student names or local Appalachian places. This practice connects students to place, but quite superficially. With regard to authenticity, is it "place-based" to have students use computer simulations to explore problems in a fictional Appalachian community similar to their own? Definitional or descriptive research (Smith, 2002) is needed to further understand the depth and authenticity dimensions of "place-based."

The implementation challenges of place-based pedagogy also require empirical analysis. Designing and implementing place-based activities that are mathematically rich requires teachers who not only know mathematics but also know the issues and circumstances of their place. The challenge is substantial. Possible research questions include: Why do some rural teachers embrace the concept while others ignore it? What support do teachers need to implement place-based activities regularly? How can place-based activities be integrated into the school curriculum? What knowledge do teachers need to create meaningful activities and to facilitate successful experiences? What specialized preparation, if any, do teachers need to create and lead effective place-based activities? What role does collaboration among teachers within mathematics departments and across other departments play in the success of place-based activities? Answers to these research questions have the potential not only to improve the quality of place-based pedagogy but also to expand the use of place-based pedagogy beyond teachers who have already embraced it.

Finally, the potential benefits and actual outcomes of place-based pedagogy need further investigation. Clearly, place-based pedagogy takes considerable time and effort on the part of teachers, students, and community members. While common sense suggests many benefits, empirical evidence is needed to determine the outcomes for teachers, students, and the community. For example, what are the costs and benefits? What are reasonable outcomes of place-based pedagogy? Is the primary purpose of place-base pedagogy to improve mathematics achievement, enhance attitudes toward mathematics, build students' understanding and appreciation of their community, improve the community, or is it all of these? Such research will not only improve the quality of place-based pedagogy, but it will also provide empirical evidence for others interested in using place-based pedagogy in their classrooms.

Strengths and challenges of collaboration. Developing and implementing this research will require collaboration. Research collaborations among rural teachers, mathematicians, and mathematics educators will enhance the mathematics teaching and learning in rural contexts. Each group member brings a necessary contribution to place-based research and activities. Rural educators and teachers know the important issues and problems in local communities and culture. They know what students need to know and should appreciate about their community or culture. Mathematicians, with their depth of knowledge of mathematics and their ability to make rich mathematical connections, "see" challenging mathematics embedded in local circumstances and cultural artifacts. They have the knowledge to judge the quality of the mathematics needed to solve problems or understand phenomena. Mathematics educators bring a variety of research perspectives and approaches to the situation and understand critical issues in teaching and learning mathematics. They can ensure that the mathematics connected to place and culture is developmentally appropriate and within reach of targeted students. They can play an important role in supporting teachers in developing meaningful activities for students.

New collaborations also provide challenges. A call for mathematics education researchers to focus efforts in rural contexts appeared in a recent editorial in the *Journal for Research in Mathematics Education* (Silver, 2003). To date, unfortunately, mathematicians and mathematics educators have failed to focus on rural culture with the same enthusiasm and depth as they have taken on issues regarding urban culture, gender, ethnicity, and race (Silver, 2003). Rural locales have served as the context for ethnographic research in mathematics education, but not as a worthy consideration in its own right. A significant challenge to mathematics educators is that rural culture is unclear and difficult to define globally. Rural contexts are different across the United States. Appalachia rural is different from Mississippi delta rural, Kansas rural, New Mexico rural, and Alaska rural. Moreover, rural is different within specific geographic areas and even within states. For example, within the same geographic area of Central Appalachia are families living in populated cities, in small cities and communities, and in highly isolated areas. The experiences, beliefs, and economics of these families can be dramatically different even though they live within 50 miles of each other. Suburban-like schools are different from small city schools, which are different from small mountainous community schools or large consolidated county schools. Further, few mathematics education researchers, especially those focusing on ethnomathematics, have chosen to study rural issues (Schultz, 2002).

Prospects for This Work

The collaborations described in this article will, I predict, be readily embraced by mathematicians, mathematics educators, and rural educators. Both groups value connecting mathematics to culture and students' lives. According to the *Principles and Standards for School Mathematics* by the National Council of Teachers of Mathematics (2000), "School mathematics experiences at all levels should include opportunities to learn about mathematics by working on problems arising in contexts outside of mathematics. These connections can be to other subject areas and disciplines as well as to students' daily lives" (pp. 65-66). Rural educators, especially those who advocate place-based pedagogy, would likely support collaboration (Haas & Nachtigal, 1998; Haleman & DeYoung, 2000; Haskins, 1999; Smith, 2002; Theobald & Curtiss, 2000).

In fact, some collaboration has already begun. The Appalachian Collaborative Center for Learning, Assessment, and Instruction in Mathematics (ACCLAIM), one of 15 Centers for Learning and Teaching funded by the National Science Foundation, has begun to support collaborations of researchers from mathematics education and rural education. The primary mission of ACCLAIM is the cultivation of indigenous leadership capacity for the improvement of school mathematics in rural areas.

Through a partnership among six universities in Kentucky, Tennessee, West Virginia, and Ohio, ACCLAIM has developed: a collaborative doctoral program in mathematics education with a rural emphasis, a leadership institute for Appalachian mathematics educators, an organization of Appalachian mathematics teacher educators, and collaborations among local schools and postsecondary institutions across Appalachia. Most importantly, it has established a research initiative that brings together researchers from two fields—mathematics education and rural education—to conceptualize and conduct research on mathematics learning and teaching in rural contexts. Over the past 2 years, ACCLAIM has stimulated conversations about improving the teaching and learning of mathematics in rural areas, building mathematics capacity in rural areas, and mathematics education research in rural areas.

All children have a right to be proficient in mathematics. They have the right to experience a mathematics that has many uses and purposes. They have the right to learn challenging mathematics connected to their lives. Mathematicians and mathematics educators have studied the role of mathematics in varied cultural contexts and learned much. Rural educators have studied education systems across America. Rural context is fertile ground on which to continue this research enterprise. By working together, both groups can provide an empirical basis for improving mathematics teaching and learning in rural communities while assisting rural teachers in revealing a mathematics that is meaningful and useful to their students. Through these collaborations, educators across rural America also can build on the existing mathematical strengths and capacities of rural areas.

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