A Research Agenda for Improving Science and Mathematics Education in Rural Schools

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We present the outcome of a conference supported by the National Science Foundation (NSF) and conducted by the Appalachian Rural Systemic Initiative. The purpose of this conference was to establish a research agenda for studying factors that impact the student learning process and student achievement in mathematics and science in rural schools. The 47 conference participants included rural, science, mathematics, and technology educators from across the country representing universities, public schools, and NSF-sponsored Rural Systemic Initiatives. Researchable questions that emerged from conference discussions are grouped into seven categories: community support, instructional resources, leadership and school reform, professional development, preservice and induction, curriculum and instruction, and database.

The *No Child Left Behind Act of 2001* (NCLB, 2002), HR1, provides billions of dollars in federal aid for education. Unlike other major federal legislation for education passed previously by the U.S. Congress, HR1 mandates that education policy and practice be "scientifically based." In response to HR1, leadership in the U.S. Department of Education (USDE) is striving to strengthen the quality of educational research. Goal 4 in the USDE's 2002-2003 annual plan seeks to "transform education into an evidence-based field" (p. 5). Many researchers are not certain whether to rejoice or to recoil, notes Feuer, Towne, and Shavelson (2002), as such a mandate could inch the field "toward a prescription of methods and a rigid definition of research quality" (p. 4).

HR1 reauthorizes the *Elementary and Secondary Education Act* and contains 111 references to *scientifically based research*. The law requires states and local school districts to demonstrate that they plan to spend the funds authorized in HR1 on programs with a scientific track record. As Feuer et al. (2002, p. 4) note: "After years of envy for federal support received by their compatriots in medical, technological, agricultural, and physical research, educational researchers can now rejoice: Research is in."

Rural Education Literature

If research is in, then a legitimate concern of policymakers and leaders in rural school districts is how future education research agendas will acknowledge the unique circumstances of educating students in rural communities. Or in some minds, will the need to find solutions to problems of "urban schooling" drive research agendas that, at best, hold only promise for application to rural schools.

Sherwood (2000) found that descriptions of research projects available on the websites of national education research centers revealed only one study that focused on rural issues and few that contained any mention of *rural* at all. Lack of adequate research and impact evaluations, coupled with definitional inconsistencies, severely limit policymakers' ability to know either the effect of federal, state, and local programs on rural schools or whether rural interests are being equitably addressed (Stern, 1994).

Scholarship on rural education in the United States is relatively sparse (DeYoung, 1987). Rural education issues rarely attract the attention of education professors at prestigious universities (DeYoung, 1991). Moreover, of the 196 doctoral dissertations written between 1989 and 1993 on

the topic of rural education (Harmon, Howley, & Sanders, 1996), the topics were limited to addressing the Federal Interagency Committee on Education's six priority topics and related questions for research and development on rural schools (Federal Interagency Committee, 1991).

Most of the usual solutions provided by educational policymakers fail to recognize the uniqueness of rural settings (Harmon, 2003a; Larsen, 1993). Clearly, if rural school educators are to adopt educational improvement initiatives that are supported by "scientifically based research," then research agendas that reflect the rural context must be pursued.

Research agendas that focus on rural schools and their communities have been offered in the past (Barker & Stephens, 1985; Carter, 1999; Dobson & Dobson, 1987; Harmon, 2002; Helge, 1986; Howley, 2000). This paper describes another, more recent, effort to create a research agenda, one that would advance our understanding of teaching and learning science and mathematics in rural school environments. It is our hope that this agenda will guide research efforts toward the end of providing scientifically based evidence of "what works" for improving student achievement in rural schools and their communities.

ARSI Research Conference

Funded by the National Science Foundation (NSF) since 1995, the Appalachian Rural Systemic Initiative (ARSI) has been working with economically disadvantaged rural K-12 public schools in central Appalachia to improve the teaching and learning of science and mathematics. One significant lesson learned during the project period was the lack of research on, and understanding of, the teaching and learning of science and mathematics in poor, rural school environments. Consequently, ARSI leadership successfully sought NSF support to hold an invitational conference for rural educators and those with experience in mathematics, science, and technology. This conference was held on May 21-23, 2001 in Lexington (KY). The conference's 47 participants included science, mathematics, and technology educators from across the country representing universities, public schools, and NSF-sponsored Rural Systemic Initiatives (Heenan, St. John, Broun, Howard, & Becerra, 2001).

Entitled "Understanding Achievement in Science and Mathematics in Rural School Settings," the general goal of the conference was to establish a research agenda regarding science and mathematics achievement in rural schools. This was accomplished through deliberative discussions involving rural education experts and persons experienced in mathematics and science education.

The conference was divided into two phases. Phase 1 involved the Research Project Advisory Council, which comprised a small group of leaders in mathematics and science education and rural education. This council met in a working session to discuss issues and questions related to improving mathematics and science education in rural schools with the expressed purpose of developing a preliminary set of researchable questions. Four commissioned papers focusing on current issues, written by leading persons in the fields of science, mathematics, technology, and rural education, provided direction for this discussion and the development of the researchable questions (Henderson, 2002).

These initial researchable questions developed by the researchers and education leaders in Phase 1 were compiled as a draft to guide discussion and further development by practitioners invited to participate in Phase 2 of the conference. Phase 2 consisted of overview presentations focusing on both rural and science/mathematics issues, a general discussion of the preliminary draft of the researchable questions, small-group analysis and refinement sessions, and a final general session to clarify the final draft of the researchable questions.

The researchable questions were edited and distributed to the Research Project Advisory Council for final revision. These questions were organized into seven categories: community support, instructional resources, leadership and school reform, professional development, preservices and induction, curriculum and instruction, and database.

Community Support

Many conference participants argued that the "community school" is the primary focus of rural education. Rural schools may be the last bastion of the traditional community and the only place that brings the entire community together regardless of age or socioeconomic status. Researchable questions in this category would guide investigations regarding how mathematics and science education is perceived and supported in rural communities.

1. What do schools and districts need to know about rural communities in order to provide relevant science and mathematics learning?

2. How do parents and community members in rural areas define *quality* science and mathematics education as compared to urban and suburban parents and community members? Does this perception vary from the perceptions of students, teachers, and administrators in each environment?

3. What mathematics, science, and technology skills are judged relevant by people in rural communities?

4. Do science and mathematics knowledge and skills used in rural communities differ from those used in urban and suburban areas?

5. What are successful ways that schools have involved rural communities in science and mathematics curriculum development, teaching, and learning?

6. What are the implications of information technology in rural areas with respect to mathematics and science learning?

7. How do rural community attitudes about science and mathematics impact instruction and student achievement?

Instructional Resources

Having adequate resources is an issue in all schools, but instructional resources in rural schools are most often the central issue for delivery of quality mathematics and science instruction. With the advent of the computer and associated information technologies, the issue of resources has become even more acute in most rural areas. Arguably, it may hold the most promise for increasing learning opportunities in such areas. Researchable questions in this category address how the disadvantages of remoteness, cost, lack of infrastructure, and lack of access might be addressed.

1. What is the accessibility, availability, use, and effectiveness of advanced digital technology to teach mathematics and science in rural schools?

2. How does the selection, purchase, and implementation of instructional materials, textbooks, and instructional technologies differ in rural schools compared to other schools?

3. How does the school's setting impact the cost per graduate of advanced mathematics and science courses in rural schools compare to the cost per graduate in schools in other settings?

4. How can the teaching and learning of science and mathematics in rural schools be improved through the effective integration of technology?

5. How can the effective use of resources, including technology, for mathematics and science instruction in rural settings be replicated? What are the indicators of the successful use of this technology?

6. What are the differences or inequities in student opportunities to use instructional resources for mathematics and science instruction because of racial, gender, or socioeconomic status in rural areas?

Leadership and School Reform

The improvement of science and mathematics education in any setting depends on leadership and the pressures for school reform. Reform of mathematics and science curricula in rural settings is problematic if school and district leaders lack adequate knowledge and understanding of mathematics and science reform movements in general. Developing this leadership for both initiating and sustaining reform in science and mathematics education is a critical issue. Another issue is how to maintain and support reform-minded leadership in rural schools. *Lasting reform* takes time to develop. The following are researchable questions in this category:

1. To what extent do leadership expectations, levels of support, and encouragement impact teachers' use of innovative strategies in mathematics and science in rural schools compared with other settings?

2. What are the factors that contribute to teachers emerging as leaders for science and mathematics program reform in rural school environments?

3. What experiences prepare teachers to serve as change-agent leaders for the improvement of science and mathematics education?

4. How can technology be used to develop leaders for science and mathematics education reform in rural school environments?

5. What leadership activities encourage the integration of technology into science and mathematics classrooms in rural schools?

6. What are the unique situations that promote a culture for innovative practices in mathematics programs in rural school settings? Are these strategies different in other school environments?

7. What strategies are most effective for developing successful science and mathematics programs in rural school settings? Are these strategies different in other school environments?

8. What are the relationships of mathematics and science standards, content frameworks, and assessment to successful implementation of standards-based mathematics and science in rural settings?

Professional Development

There are many issues surrounding the professional development of mathematics and science teachers. Many mathematics and/or science instructors are teaching in a secondary teaching area or out-of-field altogether. And for those who have appropriate certification and sufficient college coursework, their content/pedagogical knowledge may be outdated (Heenan et al., 2001; Henderson, 2002). This state of affairs is particularly acute in rural areas, where in-service opportunities for mathematics and science teachers are often inadequate or unavailable (Harmon, 2003b). Researchable questions in this category focus on the characteristics of rural-school teachers and the environments in which they teach.

1. What is the relationship between teacher qualifications/characteristics and student learning in mathematics and science in rural areas, and how does this compare to the relationship reported in other settings?

2. What characteristics of rural mathematics and science teachers are related to their perception and use of instructional technologies?

3. How do the resources that rural science and mathematics teachers use when they need help differ from the resources used by teachers in other settings?

4. What are the characteristics of highly competent mathematics, science, and technology teachers that predict persistence in a teaching career in rural school settings?

5. How do career paths of advanced mathematics and science teachers in rural schools differ from teachers in other settings?

6. What forms of professional development are effective for improving the content/ pedagogi-

cal knowledge of science and mathematics teachers in rural areas?

7. What state and local policies encourage rural mathematics and science teachers to continue their content/pedagogical training beyond their initial licensure program?

Preservice and Induction

Conference participants believed that few, if any, preservice teacher education programs prepared teachers for teaching in rural areas. Although many of the conventional and alternative licensure programs place candidates in rural schools for field experiences, there is little evidence that these programs incorporate specific experiences related to teaching in such schools, particularly those having high levels of poverty. Researchable questions in this category are as follows:

1. What are the characteristics of successful teacher education programs that are designed to prepare mathematics and science teachers for teaching in rural schools?

2. What are the transition-into-higher-education activities that colleges should conduct for entering high school graduates with interests in majoring in mathematics and science or in preparing to become mathematics and science teachers?

3. What motivates one to become a science or mathematics teacher in a rural area in contrast to other settings?

4. What strategies are successful for recruiting and retaining mathematics and science teachers in rural areas? How do these strategies compare to those found to be successful in other settings?

5. What factors are related to the subsequent utilization of preservice knowledge and skills by first-year mathematics and science teachers in rural areas, and how do these factors compare to those that pertain to comparable teachers in other settings?

6. What are effective uses of technology and virtual learning in preparing and supporting mathematics and science teachers for assignments in rural communities?

7. What factors encourage females and males from rural areas to pursue higher education in mathematics, science, and technology?

Curriculum and Instruction

What is taught, how it is taught, and the student learning that results arguably are the primary concerns for educators, rural or otherwise. In large part, such considerations determine whether a student will become proficient in mathematics and science. The following are researchable questions in this category:

1. How are content standards in mathematics and science translated into curricula and instruction in rural schools in comparison to other settings?

2. How do the science and mathematics curricula *that are taught* compare to textbook curricula and district curricular guidelines in rural settings, and how does this comparison differ from that found in other settings? Does a similar picture emerge when one focuses on advanced courses?

3. Is informal education in mathematics and science more influential in rural schools than in other settings?

4. How can teachers in rural schools make mathematics and science more relevant to the lives of their students?

5. What professional development opportunities best address the need to help out-of-field teachers become proficient in teaching a standards-based curriculum in mathematics and science?

6. How do traditional gender roles impact mathematics and science achievement in rural schools? Do traditional rural gender roles impact the courses chosen in science and mathematics?

7. What instructional strategies promote mathematics and science achievement in rural schools, and are these strategies similar to those found in other settings?

8. How do the mathematics and science assessment strategies used by rural teachers differ from those used by teachers in other settings?

Database

There are federal, state, and local databases that are of potential use toward the improvement of mathematics and science instruction in rural settings. However, these databases are not synthesized and available in usable formats. Once synthesized and easily accessed, these data would permit analyses that speak to the condition of mathematics and science instruction in rural communities. *School* profiles would provide helpful background information for studying teaching and learning in such settings. Each profile should include teacher and principal tenure, student dropout rate, teacher retention rate, class and school size, and other information deemed of potential relevance for this purpose. *Community* profiles would also be helpful as background information. These might include assets mapping (e.g., businesses, organizations, services), community views of innovation, communication issues, ethnicity, and demographic variables that may impact mathematics and science instruction.

The researchable questions for this category would contribute to the general knowledge base of teaching and learning science and mathematics in rural schools.

1. What are the socioeconomic issues related to instruction and student achievement in mathematics and science instruction in rural settings as compared to urban and suburban areas? Do these same socioeconomic patterns surface in advanced mathematics and science courses?

2. How is success in mathematics and science defined in rural areas compared to other settings? How do parents, students, the community, the state, and the nation define success in mathematics and science?

3. How do capacity issues (e.g., leadership, teacher turnover, instructional resources) influence mathematics and science achievement in rural schools?

4. What factors distinguish rural schools that excel in mathematics and science from rural schools that do not?

5. What factors contribute to out-of-field teaching in science and mathematics in rural settings? Are these factors different in other settings?

Other Issues

Conference participants raised other issues, which resulted in significant themes for conducting rural education research. One theme was that research on mathematics and science education in rural schools should not be restricted to the rural circumstance only. Rather, these findings should be compared to what is known about mathematics and science education in suburban and urban settings.

The heterogeneity of rural settings surfaced as a second theme. For example, the education circumstances in rural Iowa differ substantially from those in the delta South, on a Native American reservation, or in the mountains of Appalachia. Conference participants noted that even within a rural county, the circumstances in the major population area are very different from the experiences in the more remote areas of the county. Consequently, cross-site studies in rural areas could provide illuminating differences, particularly in terms of the implementation of new curricula for mathematics and science.

A third theme was gender. For example, in some rural areas girls traditionally may not be expected to complete higher level mathematics or science compared to boys. Moreover, differences in teaching and learning mathematics and science may be linked to the gender roles traditionally associated with their anticipated life's work after school in the rural area. Boys also may be a victim of the socioeconomic realities that placed maximum value on traditional blue-collar jobs requiring little education, lifeways that honored physical labor over scholarship (Heenan et al., 2001).

Finally, technology emerged as a fourth theme. While applications of technology have connected remote rural areas to the entire world, the potential of technology for improving teaching and learning of mathematics and science in rural schools remains largely unknown (cf., Coladarci, 1993).

Conclusion

HR1 requires that school-improvement strategies be grounded in scientifically based research in order for states to receive funds authorized in the Act. Numerous writers have called for a research agenda that is responsive to rural schools and their communities. Still, the current research base for mathematics and science education in rural contexts is extremely limited, resulting in few education reform efforts that are tailored for rural schools. In short, it is largely unknown that "what works" in urban and suburban contexts will work in rural schools.

It is our hope that the research agenda proposed at the ARSI conference will guide both short-term and long-term empirical investigations related to mathematics and science education in rural schools. HR1 provides an unprecedented

call for scientifically based research. By enacting the research agenda we have outlined, rural education researchers will be taking a significant step forward toward identifying the important—and possibly unique—influences on student learning in mathematics and science in the rural context.

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