FALL 2004
Vol. 16, No. 3

WCER RESEARCH highlights

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School Organization That Supports Teaching for Understanding

Efforts to reform mathematics and science instruction in schools must address three key organizational challenges:

1. Providing resources;

2. Aligning commitments; and

3. Sustaining and generating reform.

This knowledge results from 8 years of collaboration among teachers, schools, and researchers at WCER's National Center for Improving Student Learning and Achievement in Mathematics and Science (NCISLA; http://www.wcer.wisc.edu/ncisla/). NCISLA researchers worked to create and study classrooms in which compelling new visions of mathematics and science are becoming the norm.

This article is the third of four parts. Part 4 will focus on what travels, what conditions are necessary for travel to occur, and how similar classrooms can be created in new settings.

Providing resources

Creating fundamental and sustained changes in teaching practices requires long-term commitments of material, human, and social resources for professional development. Teachers in the NCISLA study said that time was their most critical material resource and that the most important use of their time was for planning and learning with other teachers. Because their expertise and knowledge about student thinking in mathematics and science were limited, teachers also said that expertise from outside the schools was essential to stimulating their investigations and learning.

The study also found that self-sustaining change (i.e., change that would endure beyond the life of the research and development project) requires professional development that alters the nature and distribution of resources available in the school and district.

When schools and districts restrict teachers to conventional roles, they prevent the school as an organization from enhancing its capacity in human and social resources. On the other hand, schools and districts enhance their capacity for change

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Gamoran Appointed WCER Director

Adam Gamoran, professor of sociology and educational policy studies at the University of Wisconsin-Madison, has been appointed WCER director. Gamoran, who has been interim director of WCER since August, joined the UW-Madison faculty in 1984 after earning his Ph.D. in education from the University of Chicago, where he also received his bachelor's and master's degrees.

He has been a faculty associate at WCER since 1985 and a faculty affiliate at UW-Madison's Institute for Research on Poverty since 1990. He chaired the Department of Sociology from 2001-2004, and over the years has served on numerous departmental and campuswide committees.

He was elected in 2001 to the National Academy of Education. He is a member of the American Sociological Association, the American Educational Research Association, the International Sociological Association and the National Society for the Study of Education. Gamoran has served on the editorial boards of several professional journals and has been a visiting professor at universities in Israel and Scotland.

Gamoran's research interests include the sociology of education, organizational analysis, and social stratification. His current projects include studies on the short- and long-term effects of school desegregation and resegregation.

"It's an honor to lead WCER at such an important time in the development of education research," Gamoran says. "The No Child Left Behind Act calls for schools to use programs and practices that are based on sound research evidence, and WCER scholars can play a leading role in providing such evidence for educators across Wisconsin and the nation."

Gamoran succeeds Andrew Porter, former professor of educational psychology, who accepted a position at Vanderbilt University. Porter led WCER from 1988-2003.

if they promote leadership roles for teachers, recast the role of administrators as one of facilitating rather than managing, change the allocation of time during the school day, and provide materials and resources suitable to new teaching endeavors.

Schools and districts foster growth of new human and social resources when they allow new roles to emerge. By contrast, schools and districts that force new initiatives to conform to existing arrays of resources risk stifling potential change or marginalizing change agents.

Sustaining reform

Sustaining teaching for understanding depends on the emergence of leadership within professional communities, a commitment to professional interdependence (rather than independence), and a commitment of human and material resources. The infusion of human and material resources must accomplish two things:

1. It must contribute to the development of social resources in ways that enable teachers to assume responsibility for leadership; and

2. It must foster and maintain communities of inquiry aimed at understanding student thinking and designing instructional practices that build student understanding.

Change can be sustained when (a) school personnel routinely evaluate, invent, and implement new practices, (b) those practices are motivated by reform and are consistent with reform, and (c) schools support teachers' professional communities and professional development. In contrast, when teachers haphazardly acquire new practices with little or no community support or professional development opportunities, new practices tend to become brittle and routine—and, at times, are abandoned altogether.

Creating similar classrooms in new settings

The teaching approach and related professional development described here are complex. Complex practices cannot, in principle, simply be codified and then handed over to others with the expectation that they will be enacted or replicated as intended.

Yet traditional views of professional development presume that teachers can be trained to faithfully enact instructional methods and strategies that have proven effective elsewhere. Carpenter and colleagues consider this an inappropriate conception of professional development—especially for teachers seeking to develop classroom practices that place students' reasoning at the center of instructional decision making. This kind of teaching requires professional development that supports teachers in creating the knowledge to adjust instruction to their students' needs and understandings.

Instructional strategies that build on student reasoning cannot simply be transferred to a new setting. By their very nature, such attuned instructional practices need to be refined by teachers who have the intellectual framework and support to analyze, evaluate, and appropriately adjust practices based on student understanding.

Instruction that revolves around student reasoning involves ambiguity and uncertainty, and teachers need support in dealing with this uncertainty. The ability to create and sustain classrooms that build on student reasoning depends on developing professional teaching communities in which teachers help each other deal with uncertainty and rely on each other as resources as they engage in ongoing discussion of teaching and learning.

From the perspective of teacher professional development, the long-term goal of reform can be framed as the creation of environments where teaching becomes a generative activity in which teachers routinely deepen their understanding of students' reasoning in specific mathematics and science domains. The critical elements required to accomplish this goal are that teachers make their classrooms sites for their own learning and that they have opportunity to participate in professional teaching communities that support teaching for understanding.

This research was funded by a grant from the U.S. Department of Education's Office of Educational Research and Improvement (R305A60007-01).

For more information:

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Romberg, T. A., Carpenter, T. P., & Dremock, F. (in press). *Understanding mathematics and science matters.* Mahwah, NJ: Erlbaum.

* Carpenter's colleagues include Maria Blanton (University of Massachusetts-Dartmouth), Paul Cobb (Peabody College, Vanderbilt University), Megan Loef Franke (University of California, Los Angeles), James Kaput (University of Massachusetts-Dartmouth), and Kay McLain (Peabody College, Vanderbilt University).

Thomas Carpenter

Producing Mathematical Justifications

Many consider proof to be central to the discipline of mathematics and the practice of mathematicians; yet surprisingly, the role of proof in school mathematics has been peripheral at best. Fortunately, the nature and role of proof in school mathematics is receiving increased attention with many math educators advocating that proof should be a central part of the math education of students at all grade levels (see sidebar, next page).

UW-Madison education professor Eric Knuth agrees. If students are to develop their competencies in proving, then proof must play a more meaningful role in their school mathematics experiences. Enhancing the role of proof in the classroom requires substantial effort by teachers to ensure that students have the means and the opportunities to engage in proving. This will be no easy task, Knuth says. Previous research has found that many students find the study of proof difficult and that many current and future teachers themselves have inadequate conceptions of proof as well as limited views of the nature and role of proof in school mathematics.

Knuth points to two ways to help teachers enhance the role of proof in the classroom. One is to help teachers learn to recognize and to capitalize on classroom opportunities to engage students in proving. Another is to design curricular materials that both support teachers' efforts to enhance the role of proof in the classroom and provide opportunities for students to engage in proving activities.

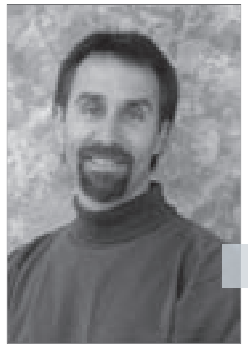
To learn more about middle school students' conceptions of proof, Knuth recently asked about 400 students to generate justifications about the truth of several mathematical propositions or statements.

(continued on next page...)

Some examples:

- If you add any two consecutive numbers, the answer is always odd.
- If you add any three odd numbers together, the answer is always odd.
- If you add any three consecutive numbers, the answer is always equal to three times the middle number.
- Take any number and multiply it by 5 and then add 12. Then subtract the starting number and divide the result by 4. The answer is always 3 more than the starting number.

Consistent with results from previous studies, the majority of students in Knuth's study tended to rely on lists of examples to demonstrate and verify the truth of a statement or proposition. For the students who did attempt to produce general arguments, Knuth found that the number and success of their attempts at generality increased with grade level. Students' expectations regarding the need to produce a mathematical justification increased with grade level as well. To some degree, these results might be a positive indication of the influence of reform; by eighth grade, the students in this study had entered their 3rd year of experiencing a reform-based curricular program—a program with an explicit emphasis on reasoning and proof.



Eric Knuth

Thus, as the curriculum provides middle school students with opportunities to engage in proving activities, some students develop an awareness of the need to justify and the need to treat the general case.

RECOMMENDATIONS

In particular, the National Council of Teachers of Mathematics *Principles and Standards for School Mathematics* (2000) recommends that prekindergarten through Grade 12 students should learn to *"recognize reasoning and proof as fundamental aspects of mathematics, make and investigate mathematical conjectures, develop and evaluate mathematical arguments and proofs, and select and use various types of reasoning and methods of proof."* In addition, results from the National Assessment of Educational Progress show that most 11th-grade students, including those who had completed a college-preparatory geometry course, performed poorly on items dealing with proof and proof-related methods.

Knuth's study raises several questions regarding students' understandings of proof that deserve continued research:

1. To what extent do students recognize that a proof treats the general case?
2. To what extent can plausible proof learning trajectories be indentified?
3. To what extent can critical transition points in students' understanding of proof be identified?
4. What is the relationship between students' proof *production* competencies and their proof *comprehension* competencies?

Knuth hopes that his work raises questions that explore students' understandings of generality as well and leads to further research on the treatment of proof in school mathematics curricula. The more educators learn about the details of student thinking with regard to proof, Knuth says, the better able they will be to support teachers in their efforts to enhance their students' understandings of proof.

Knuth's research is funded by the National Science Foundation.

For more information see http://labweb.education.wisc.edu/knuth/mathproject/data/index.html and http://www.education.wisc.edu/ci/mathed/knuth/index.html.

Supporting Change in Teachers' Assessment Practices

The standards-based reform approach to instruction assumes that teachers will use evidence from several sources to inform instruction. But to do this effectively, teachers need help to develop their ability to monitor student progress. Teachers using reform mathematics curricula need tools and methods to build their capacity to assess student learning. Teachers can learn to use such practices in their classrooms, but they need the support of appropriate professional development.

According to recent research by UW-Madison education professor Thomas A. Romberg and colleagues, the assessment methods teachers use with new reform curricula are initially grounded in older practices that focus on mastery of skills and procedures. In the absence of on-site support, teachers face difficult challenges in selecting appropriate assessment tasks and adopting the inquiry techniques intended by the developers of reform curricula such as *Mathematics in Context (MiC)*. The *MiC* middle grades curriculum was developed by the staff of the Freudenthal Institute at the University of Utrecht, The Netherlands, and the staff of the National Center for Research in Mathematical Sciences Education at the Wisconsin Center for Education Research.

Romberg and colleagues worked with teachers who were implementing the *MiC* curriculum. These teachers realized a need for change in their assessment practices after they saw the quality of students' work that was not being captured by conventional quizzes and tests, including students' ability to construct reasonable justifications for their assertions.

Over time, these teachers developed a more comprehensive view of assessment as an ongoing process. They began to use a wider range of assessment tasks and strategies. The increased attention to student learning via assessment motivated the teachers to study further the relationship between mathematics content and instruction and to explore the evolution in students' understanding as they progressed from informal to formal reasoning in mathematical domains.

Teachers' concerns about assessment are not restricted to tests and quizzes, Romberg says. His research into teachers' instructionally embedded assessment practices reveals that teachers want to use assessment in a variety of instructional contexts. One teacher reported offering more purposeful instruction after she restructured and redefined her grading system. These changes motivated her to further study her students' ways of representing and communicating their understanding of mathematics *during* instruction.

When teachers explore and reflect on their own ways of formally assessing student understanding, their inquiry is likely to influence the instructional activities they choose, the questions they ask students, and the content of the classroom discussions they guide. Teachers' motivation to explore student thinking also may require giving additional attention to classroom norms so that students can safely share their emerging conceptions. Such changes mean taking risks, however, with consequences that initially seemed uncertain at best to the teachers in Romberg's studies.

To support teachers' efforts to change their assessment practices, districts and schools need to implement relevant, ongoing, interactive professional development programs over which the teachers themselves have considerable control. Such professional development programs should incorporate the following four components:

1. ***An opportunity for collaboration with other teachers.*** Teachers value discussing rubrics and grading systems, as well as their own views (e.g., "Include multiple opportunities for students to demonstrate what they learn"; "A few good tasks can be used to demonstrate understanding. You do not need 20+ items".).
2. ***A "lifeline" to technical support.*** Teachers do not want research staff to dictate what they should do, but they do want researcher expertise available as needed.
3. ***Time.*** Change is not easy, but as teachers set aside time to work through curricular materials and discuss the activities' mathematical goals, they gradually become comfortable with the instructional process and, in turn, the assessment possibilities.
4. ***Support for experimentation.*** Teachers need administrators and other teachers to value their efforts to make changes.

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Class Size Reduction Program Offers Benefits

A program developed to help improve student academic achievement by reducing class size has led to positive results in Grades 1–2 and mixed results in Grades 3-4, according to a recent study conducted by WCER researchers Norman Webb and Robert H. Meyer, with colleagues Adam Gamoran and Jianbin Fu.

Wisconsin's Student Achievement Guarantee in Education (SAGE) program aims to boost student academic achievement by requiring participating schools to

- reduce the student-teacher ratio to 15:1 in K–3 classrooms;
- remain open extended hours;
- develop rigorous academic curricula; and
- implement plans for staff development and professional accountability. (See sidebar next page.)

The major question guiding Webb and Meyer's study was: How does SAGE affect students' state test performance after they have been in SAGE for 3 or 4 years?

Webb and Meyer focused on three cohorts—students in Grade 1 in 1996–97, 1997–98, and 1998–99—who stayed in the same SAGE or comparison school from Grade 1 to Grade 4. The study found that participation in SAGE had a positive and statistically significant effect on student scores on the Comprehensive Test of Basic Skills-TerraNova tests in reading, mathematics, and language arts through the end of Grades 1, 2, and 3 that were administered as part of the program. This finding confirmed the results of a 2003 UW-Milwaukee study that found a statistically significant gain by SAGE students compared to the contrast group over Grade 1, a gain sustained over the next two grades.

However, Webb and Meyer's study found conflicting results when it considered SAGE's effect on student performance on the Grade 4 Wisconsin Knowledge and Concepts Examination (WKCE). Participation in the SAGE program had no cumulative effect on the Grade 4 examination in reading, mathematics, and language arts; that is, the effect detected for the SAGE program was not statistically different from zero. This result could imply that the effects observed in Grades 1-3 were not sustained, Webb says.

Moreover, the study found no cumulative effect for the SAGE program on the Grade 3 Wisconsin Reading Comprehension Test (WRCT). Thus, with the same group of students—those in Grade 3 in the same school year—the Grade 3 WRCT and the Grade 3 TerraNova reading test produced conflicting results on the effectiveness of the SAGE program. The WRCT results indicated no significant effect, whereas the TerraNova results indicated significant cumulative effects. This inconsistency indicates that the true effects of the SAGE program cannot be determined with any sufficient degree of certainty using available data.

Webb and Meyer's SAGE analysis did not consider the different approaches schools and teachers used to reduce class size. Webb says such an analysis could produce evidence (a) that some approaches are more effective than others for increasing performance on the state assessments and (b) that when the SAGE program is administered in specific ways and accompanied by professional development, it does indeed give students in primary grades an advantage.

The data do raise the possibility that the SAGE program has a more positive effect on African American students than on White students. Although the fourth-grade WKCE data did not show a significant difference in the performance of these two groups, the cumulative differences were in a direction suggesting the possibility of a greater impact of the SAGE program on African American students. No comparable differences were found when the performance of students from low-income families was compared with that of students from high-income families.

For more information, see the full report

http://facstaff.wcer.wisc.edu/normw/SAGE/sage_report.htm.

Funding for this research was provided by the Wisconsin Department of Public Instruction.

Norman Webb

SAGE in Wisconsin

Beginning with the 1995–96 school year, any district in Wisconsin that had at least one school serving 50% or more children living in poverty was eligible to apply for participation in the SAGE program. In addition, in each eligible district one school with an enrollment of at least 30% or more children living in poverty could participate. In Milwaukee, up to 10 schools could participate. Participating districts received $2,000 per student and were required to meet specific contractual requirements of the state's Department of Public Instruction.

SAGE was created as a 5-year pilot program requiring annual evaluation of participating school districts. Evaluation of the program's first 3 years showed that students in the SAGE schools scored significantly higher than students in the contrast schools in reading, language arts, and mathematics.

In the 2000–01 school year, the state provided an additional $37 million to allow approximately 500 more schools to join SAGE. The Wisconsin biennial 2003–05 budgets maintained the total SAGE aid available at $95 million. The calculation of this aid continued to be based on $2,000 per low-income K–3 pupil. In the 2002–03-school year, nearly 550 Wisconsin elementary schools participated in SAGE.

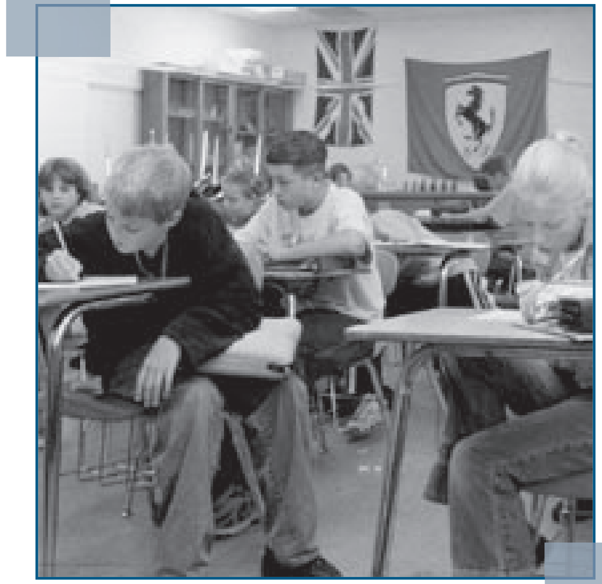
(SUPPORTING CHANGE...*continued from page 5*)

Effective professional development programs can, in turn, generate external professional networks that offer further support.

Researchers and teachers identify the challenges teachers face as they attempt to implement new assessment procedures in conjunction with their use of *MiC* curriculum materials in the new book, *Standards-Based Mathematics Assessment in Middle School: Rethinking Classroom Practice.* The volume is edited by Romberg and published by Teachers College Press (2004). Topics include teaching and assessing under a reform curriculum, designing new assessment tasks, embedding assessment in instructional practice, and generalizing the approach.

Funding for development of the MiC curriculum was provided by the National Science Foundation.

Thomas Romberg



WCER RESEARCH highlights

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WCER Research Highlights is published by the Wisconsin Center for Education Research, School of Education, University of Wisconsin–Madison. WCER is funded through a variety of federal, state, and private sources, including the U.S. Department of Education, the National Science Foundation, and UW–Madison. The opinions expressed in this publication do not necessarily reflect the position, policy, or endorsement of the funding agencies. Fourth-class, bulk-rate postage is paid at UW–Madison, Madison, WI. Send changes of address to WCER, 1025 West Johnson Street, Madison, WI 53706 or call (608) 263-4200. Include the address label from this issue.

WCER Research Highlights is available on the Web at http://www.wcer.wisc.edu.

ISSN 1073-1822
Vol. 16, No. 3
FALL 2004

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