



WCER Highlights

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30 years of mathematics education research



Learning with understanding means more than being able to produce correct answers to routine problems.

Researchers and educators have learned a lot about the teaching and learning of mathematics in schools during the past 30+ years, much of it from the work of the emerging mathematics education research community. However, UW-Madison education professor emeritus Thomas A. Romberg says researchers and educators still have lots to learn about the teaching and learning of mathematics in the “messy” social environment of school classrooms.

For research to be productive and useful in any discipline, it must be conducted within a research community. Mathematics education is a relatively young academic field, and research on the teaching and learning of mathematics is even younger. A research community in mathematics education has only gradually begun to emerge in the past half century, and the process is still ongoing.

Reviewing mathematics education research, Romberg identifies 12 findings that distinguish what is known today from what was known in the 1960s. The first five come from research conducted by the National Center for Improving Student Learning and

WCER Highlights



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FROM THE DIRECTOR



WCER welcomes two new Centers

Improving mathematics and science education has been at the core of WCER's work for decades. We continue that tradition with the introduction of two major new projects funded by the National Science Foundation. System-Wide Change for All Learners and Educators (SCALE) aims to reform math and science education, Grades pre-K through 12. It involves a UW–Madison partner-

ship with the University of Pittsburgh and four school districts around the country. Another new project, the Center for the Integration of Research, Teaching and Learning (CIRTL), is part of a network of NSF Centers for Learning and Teaching. Together, these two centers address reform in grades kindergarten through college. They seek to develop a national science, engineering and mathematics faculty with teaching skills that will enable all college students to be scientifically literate.

I call my friend and colleague Tom Romberg “Mr. Math Education” because for decades he has made significant contributions to the nation’s mathematics policy. In this issue Tom reviews his more than 30 years of research and discusses several things mathematics educators know today that they didn’t know in the 1960s.

Systemic reform offers the possibility of fundamental improvement in American education. A question that remains is, how precisely can one measure student achievement resulting from systemic reform efforts? WCER researcher Norman Webb and colleagues recently identified three factors that can influence such measurement.

Also in this issue, UW–Madison education Professor Richard Halverson shares a story that illustrates how a home-grown program in a Chicago urban school succeeded in increasing the achievement of students of color and low-income students. The school principal launched a voluntary, monthly “breakfast club” at which teachers gather to discuss their practice.

You’re invited to spend time at our web site, www.wcer.wisc.edu. There you’ll find research findings and news items beyond what we report in this newsletter.

Andy Porter

Achievement in Mathematics and Science on student learning with understanding, located at WCER.

1. Educators have underestimated students’ capability to learn mathematics with understanding. Given the opportunity to explore a domain using a set of structured activities, *all students can learn important mathematics with understanding.*
2. Learning the concepts and skills in a mathematical domain requires that students be engaged in a rich set of structured activities over time. Specifically, students need an oppor-

tunity to investigate problems that encourage *mathematization*. By that is meant problems that are subject to measurement and quantification, that embody quantifiable change and variation, that involve specifiable uncertainty, and that involve our place in space and the spatial features of the world we inhabit and construct. In addition, problems should encourage the use of languages for expressing, communicating, reasoning, computing, abstracting, generalizing, and formalizing. Such problems require systematic forms of reasoning and argument to help establish the certainty, generality, consistency, and reliability of students’ mathematical assertions.

3. Learning with understanding involves more than being able to produce correct answers to routine problems. Mathematics should be viewed as a human activity that reflects the work of mathematicians—finding out why given techniques work, inventing new techniques, and justifying assertions. Learning with understanding occurs when it becomes the focus of instruction, when students are given time to discover relationships and learn to use their knowledge, and when they reflect about their thinking and express their ideas. Doing mathematics cannot be viewed as a mechanical performance or an activity that solely involves following predetermined rules.
4. *Modeling* and *argumentation* are important aspects of mathematics instruction that foster learning with understanding. Modeling offers a way to represent phenomena in the world by means of a system of theoretically specified objects and relations. Modeling is critical in developing understanding in a domain. In classrooms, it is important to consider modeling as a cycle comprising model construction, exploration, and revision. Additionally, as students make conjectures, they need to learn to justify them. Thus, argumentation and standards of evidence, with an emphasis on promoting students’ skills for generalization in mathematics, are critical.
5. Student learning should be seen as a product of situated involvement in a classroom culture. Learning with understanding is a product of interactions over time with teachers and other students in a classroom environment that encourages and values exploration of problem situations, modeling, and argumentation. The very nature of mathematics is defined communally, making participation by all not only a fundamental civil right, but also a critical prerequisite to the continued vitality of mathematics in the nation.



The very nature of mathematics is defined communally.

Romberg also points to four general findings from research on teaching. The reform approach to teaching represents a substantial departure from most teachers' prior experience, established beliefs, and present practice.

6. Teacher knowledge of student thinking is critical. Teachers need to listen and hear what students are saying as they conjecture and build arguments. Teachers also need to judge the quality of students' justifications and explanations in examining student work.
7. Teachers must understand the structure of mathematical domains. Knowledge of the network of relationships in a domain is critical when making decisions about student understanding and the sequence of instruction.
8. Rather than just cover the content in a textbook, teachers need to base instruction on the needs of their students. This finding follows directly from the previous two. If teachers know the level of their students' thinking, and understand how it fits within the structure of the domain of interest, then they can design appropriate instruction.
9. Professional development cannot be done well in isolation. Professionalism is the key to quality classroom instruction, but it can only be achieved if teachers join together to collaboratively undertake professional assistance.

Finally, one of the key aspects of teaching has always been monitoring students' progress. Mathe-

matics teachers have traditionally done this by giving curriculum-based quizzes and tests, scoring and counting the number of correct answers on each, and periodically summarizing student performance in a letter grade. Unfortunately, this standard approach to assessment is not consistent with what educators now know about how students learn mathematics.

10. External tests have an effect on instruction in that teachers take classroom time to prepare students to take the test. However, such tests are not often well tailored to classroom instruction, nor are the results useful for monitoring growth over time.
11. Curriculum-based quizzes and tests tend to include items that are very similar to exercises in daily lessons and that reflect reproduction, definitions, or computations. Such instruments rarely contain items that require students to relate concepts or solve nonroutine problems.
12. Most mathematics teachers are aware that they acquire considerable informal evidence about their students, yet they rarely use such evidence in judging student progress. In fact, current data show that most mathematics teachers could benefit from professional development designed to help them learn how to make good use of their informal assessments.

Schools are social and political organizations that operate within a coherent set of traditions. Changing such organizations involves understanding and dealing with the partisan political and ideological perspectives on schooling that permeate our society.

Researchers and educators who hope to ground school procedures in the findings of research rather than in politics and ideology are likely to face either of two arguments: that the research is based on grossly unrealistic reductions of complex phenomena, or that it involves conflicts of value that cannot be resolved by evidence. In fact, Romberg believes it is naïve to believe that research findings can curtail partisan prejudices about schooling. Nevertheless, research is increasingly providing insights, understanding, and new approaches that lead to instruction that more effectively promotes student achievement.

For more information contact Romberg at trromberg@facstaff.wisc.edu.

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Romberg

Thomas A. Romberg is Sears Roebuck Foundation-Bascom Professor of Education at the University of Wisconsin-Madison. His research has analyzed young children's learning of initial mathematical concepts, methods of evaluating students and programs, and the integration of research on teaching, curriculum, and student thinking.

Romberg was a leader in the development of the National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards for School Mathematics (1989). He is former director of WCER's National Center for Improving Student Learning and Achievement in Mathematics and Science. He offers these observations looking back over a career spanning more than 30 years.

Measuring effects of systemic initiatives



Do systemic initiatives improve student achievement? New measurement tools point toward answers.

Since public schools were first instituted in the United States, society's needs have changed. One way for education to keep up with a changing society is through piecemeal reform—that is, programs that offer improvement in specific areas of student achievement. Systemic education reform, on the other hand, offers the possibility of fundamental improvement in American education.

Demonstrating the effects of systemic education reform is difficult, given its complexity. However, a recent study by Norman Webb and WCER colleagues demonstrates analytic techniques that can be used to study the effects of systemic reform on growth in student learning over time.

Webb and colleagues analyzed data from the Texas Assessment of Academic Skills (TAAS) for Grades 3 through 8, focusing on the years 1994 through 2000. They then compared student achievement in Urban Systemic Initiative (USI)¹ districts with achievement in other Texas districts. Webb's analysis produced evidence of improvement in student learning in USI districts as compared with other districts. Specifically, the team found that:

- ▶ Students' TAAS scores in USI districts improved from 1994 to 2000 for all groups. Annual gain scores by Black and Latino students improved over time relative to those of White students.
- ▶ Overall, student achievement scores in USI districts began lower but improved faster than those in non-USI districts.
- ▶ Comparing USI and non-USI districts, one finds no difference in the rate at which gaps in achievement among students of different socio-cultural backgrounds are narrowing.

Questions addressed

Webb's multidisciplinary research team worked for over a year to develop an analytic framework for studying the degree to which systemic reform contributes to improved student achievement and other outcomes.

For example, team member Dan Bolt examined changes in school mean scores on TAAS at a given grade level (e.g., Grade 5 in 1994, 1995, 1996, etc.). He believed this approach would more effectively control for teacher effects because the same



teachers are more likely to teach the same grade in successive years.

Meanwhile, Adam Gamoran used nearly all of the students in the database to estimate the growth intercepts and slopes. In this model, students with any two scores, even those whose scores are not for consecutive years, can be used to estimate the parameters.

Robert Meyer examined students' performance in a grade by considering their achievement from the year before. His analyses included students who had test scores for two consecutive years. The advantage of this approach is that improved student performance can be measured more precisely than if only one school year is considered.

All three approaches produced evidence that USI school districts had at least a small positive effect on student achievement. However, because of the lack of more specific information on USI activities, Webb cautions that the models could not definitively answer the question of whether the effects were directly related to USI participation.

The team did provide information to NSF that will enable NSF, its education constituencies, and education researchers to address the following questions:

- ▶ How can the data submitted to NSF by systemic initiatives be used to evaluate systemic reform?
- ▶ How does the precision of analysis depend on the qualities of student assessment data?
- ▶ What statistical models best fit the data linking systemic initiatives to student achievement?
- ▶ What are the lessons learned about the kinds of databases and analyses that are most effective for evaluating and understanding systemic reform?

Factors affecting precision

Webb and colleagues identified three general factors that can influence the precision of analyses of student achievement data in relation to systemic reform:

1. The extent to which teachers, schools, and districts participated in the systemic initiative over time. Classifying schools by their degree of participation in systemic initiatives would allow comparing school performance and would provide more precise information.
2. The types of students excluded from the testing and analyses; and
3. The standard error of measurement in the assessment instruments.



Achievement scores began lower but improved faster in USI districts.



Webb

Webb and colleagues hope that the analytic models they developed for this study will be widely applicable to other studies of large-scale reform. In fact, the most important contribution of the study, according to Webb, is its potential to inform the design of other evaluations of large-scale reform efforts and thus to increase the likelihood that data will be available in the future to more effectively measure the impact of such interventions on student learning.

Webb cautions that there is no one best model for analyzing the link between systemic initiatives and student achievement. Each model is based on specific assumptions made necessary by the limitations of available data or other constraints.

The research conducted by Webb and colleagues was supported by the National Science Foundation. For more information, contact Webb by e-mail at nlwebb@facstaff.wisc.edu or by telephone at (608) 263-4287.

1. NSF launched the USI program in 1994, applying lessons learned from its earlier State Systemic Initiative (SSI) program to the problems of inner-city school systems. The USI program was offered to major cities with the largest number of K-12 students living in poverty.

WCER hosts two new NSF research centers

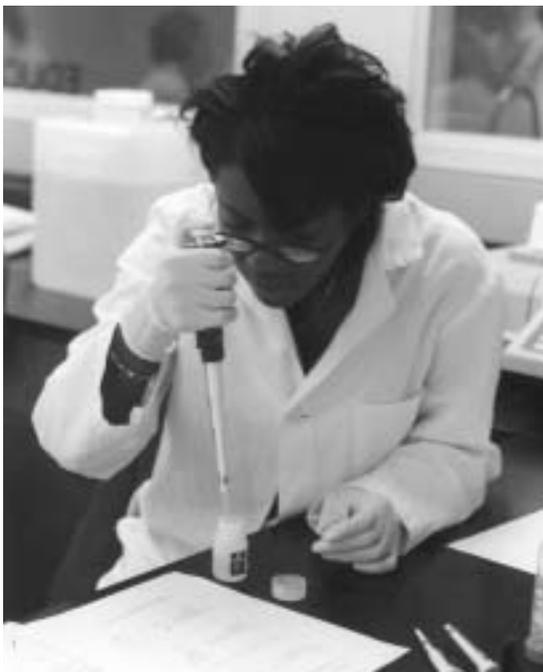
The National Science Foundation has awarded WCER \$45 million over the next 5 years for two new mathematics and science education research centers, System-Wide Change for All Learners and Educators (SCALE) and the Center for the Integration of Research, Teaching and Learning (CIRTL).

SCALE aims to reform math and science education, Grades pre-K through 12. It involves a UW–Madison partnership with the University of Pittsburgh, the Los Angeles Unified School District, Denver Public Schools, Providence Public Schools, and the Madison (Wis.) Metropolitan School District. SCALE is bringing together mathematicians, scientists, social scientists, and education practitioners to improve the math and science achievement of all students at all grade levels in the four school districts. Students will be engaged in deep and authentic science and mathematics instructional experiences. Documentation of what works and information about how to construct such a partnership will be made available to policymakers and university and school leaders.

SCALE is directed by Terrence Millar, UW–Madison Professor of Mathematics and Associate Dean of the Physical Sciences, Graduate School.

The new Center for the Integration of Research, Teaching and Learning (CIRTL) promises to transform the UW–Madison into a working laboratory for helping graduate students and faculty develop teaching skills that match their research skills. Part of a network of NSF Centers for Learning and Teaching, CIRTL seeks to develop “a national science, engineering and mathematics faculty with teaching skills that will enable all college students to be scientifically literate, and that will promote a public better prepared to live in a high-tech world,” says Robert Mathieu, a UW–Madison astronomy professor and the principal investigator of the new initiative.

CIRTL aims to help ensure that math and science are taught well not only to the select few undergraduates who go on to advanced degrees and careers in these fields, but also to students who will encounter only a minimum of science and math coursework. “All students should profit from improved instruction in undergraduate math and science, not just those pursuing a major,” says Mathieu. “Students of color and women, for example, are less likely to take math and science courses as undergraduates. Even when they do, they are less likely to pursue further study in those disciplines.”



CIRTL will aim for improved instruction in undergraduate math and science nationwide.

CIRTL will research and implement ways to increase the effectiveness of teaching approaches for all undergraduate students and thereby enhance success in science courses for diverse audiences.

CIRTL is a partnership of UW–Madison with Michigan State and Penn State Universities.

These projects join WCER's other recently funded NSF Center for Learning and Teaching, Diversity in Mathematics Education (DiME). DiME aims to develop and enhance the instructional workforce from kindergarten through graduate school. The program consists of three interrelated components: a doctoral/postdoctoral component; a teacher education component for teachers and instructional leaders; and a comprehensive research agenda. These components are integrated by a focus on the ideas of algebra and issues related to learners with diverse cultural, language, and cognitive backgrounds. DiME is directed by Walter Secada, UW–Madison professor of curriculum and instruction.

The centerpiece of DiME is its community of scholars, including the faculty, doctoral and master's degree students, participating teachers, and undergraduates who will engage in collective analysis of cases of mathematical learning and teaching using Web-based software.



Mathieu



Millar



Breakfast, anyone?

Home-grown professional development program succeeds

Richard Halverson works to make the wisdom of successful leadership practice available to interested practitioners. Schools are very often mandated to change without principled opportunities to learn from successful peers. His current research with associate Colleen Capper aims to create multimedia cases of leadership practice that

- ▶ communicate the goals and resources required for leaders to engage in school change, and
- ▶ tell the story of how practitioners weave resources together to form coherent practice in their schools.

Practical wisdom is disclosed in the ways that school leaders set and solve problems in their schools. Halverson looks at locally-designed programs, which he refers to as artifacts, that provide a window into the practical wisdom of school leaders. In one case Halverson studied recently, one school's "breakfast club" showed how school leaders saw student achievement as a matter of improving the professional community in the school. Breakfast Club was one of the tools school leaders used to help develop and guide the emergent sense of professional community.



Halverson

Teaching does not begin and end in the classroom. A teacher's experiences with other faculty members, with the school's leaders, and with its organizational structure all have a profound effect on the teacher's influence on students.

UW–Madison education professor Richard Halverson and colleagues documented the practices of public school principals from a variety of communities who succeeded in increasing the achievement of students of color and low-income students. They recently found a Chicago public elementary school that raised its student achievement scores after the school principal launched a voluntary, monthly "breakfast club" at which teachers could gather to discuss their practice. Halverson was particularly interested in this innovative program as a model of *distributed leadership*—that is, leadership that emerges through the interaction of leaders and followers in the execution of both the everyday tasks of leadership (the micro tasks) and the school's overall instructional goals (the macro tasks).

Adams School is a Chicago neighborhood elementary school with about 1,200 students (largely African American) housed in two sites. Adams is widely recognized as a school with a well-articulated vision and a record of instructional change. Over the past 10 years, Adams has recorded demonstrable gains in student performance on high-stakes district and state assessment measures, and school leadership is given much of the credit for these improvements.

The breakfast club originated in 1995, when Adams School began hosting the monthly meetings to create professional community and provide an opportunity for teachers to review research on best instructional practices. Although several teachers at the school already kept abreast of cur-

rent developments in the field, the school's professional development efforts rested largely on outside expertise, and they were too intermittent and variable in quality to have a long-lasting impact on student achievement scores.

In interviews with the school's administrative team, Halverson learned that:

- ▶ Faculty members did not want the breakfast club to be mandatory;
- ▶ The substance of the discussions needed to sell the program;
- ▶ The club should meet in the morning, so that teachers would be fresh and ready to entertain new ideas;
- ▶ The assigned readings should be kept short;
- ▶ Teachers should be permitted to select the readings and lead the discussions; and
- ▶ The readings should align with the school's instructional priorities and the teachers' classroom practice.

Innovation becomes institutionalized

The breakfast club was designed to acquaint teachers with relevant research in reading and writing, to help them "work smarter, not harder," in their efforts to help students improve their reading and writing skills. A persistent underlying goal was to improve student test scores in language arts on district standardized tests.

The Adams School leadership team recognized that improvement of student test scores might not result from a traditional professional development program using external consultants. Principal Brenda Williams realized that long-term gains in student test scores would more likely come when teachers had the opportunity to talk with one

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Breakfast

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another about their teaching and that the monthly breakfast club would stimulate such conversations.

After 2 years, attendance at the breakfast club averaged about 75% of the school's teachers. The program was modified over time to add incentives for teachers to participate. For example, the principal encouraged teachers to lead a breakfast club discussion. Attendance increased as the veteran faculty members realized that they would be asked to lead discussions and therefore needed to find out what the breakfast club was about.

More than 6 years later, the breakfast club has become an institution at Adams School, and over the past 4 years, student achievement scores have risen 22%. Teachers and administrators credit the breakfast club as a key element in creating the kind of professional community necessary to develop a programmatic, cross-grade level approach to teaching reading and writing in the school.

The breakfast club resulted in significant change for Adams staff. It provided an opportunity for a school-wide professional community around language arts instruction. This professional

community, in turn, was credited for student test score gains in reading and writing. The club also helped make teachers take ownership of their professional development. And the documentation of breakfast club practice has given Adams School leaders an opportunity to reflect on their practice, discern patterns, and make sense of instructional initiatives that originally evolved in practice.

Through a retelling of the breakfast club story, Halverson and colleagues have identified several of the guiding principles of leadership practice at Adams School, including:

- ▶ The importance of patience while waiting for a voluntary program to take hold;
- ▶ A commitment to considering research that is directly relevant to teacher practice; and
- ▶ A continued willingness to use collaborative design as a method for solving emergent school problems.

Halverson's current research is sponsored by the DeWitt Wallace-Reader's Digest Fund. With UW–Madison Education Professor Colleen Capper, Halverson is documenting and communicating leadership practices for students who traditionally struggle. For more information, contact Halverson at halverson@education.wisc.edu

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