



WCER RESEARCH highlights

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Algebra Instruction, Then and Now

When the National Council of Teachers of Mathematics (NCTM) issued its *Curriculum Focal Points* document this past September the nation witnessed a flood of media response. Unfortunately, many articles, editorials, and op-ed pieces missed the point. Some gleefully pronounced that the days of “fuzzy math” were over and that the NCTM was “admitting” that it had made a “big mistake” back in 1989 when it released its *Curriculum and Evaluation Standards for School Mathematics*. Writers in newspapers large and small cast the NCTM’s new Focal Points document as “backpedaling.”

In response to these misunderstandings, NCTM president Skip Fennell explained that the new *Focal Points* document does not “undo” anything, but rather sets clearer, more common goals for math learning by focusing on a number of crucial, agreed-upon concepts. The document offers paragraph-long descriptions of concepts the authors regard as essential at each grade level, broken out by topics such as numbers and operations, basic algebra, measurement, and geometry. Those expectations become more demanding with each grade.

Impassioned editorial discussion about mathematics standards and instruction is a welcome change from the norm. But it’s important to note that this recent flurry of opinions generally omitted two crucial and equally important parts of reforming mathematics instruction. It’s not just about curricular expectations: Reform also includes getting inside the teachers’ heads to determine what they think about their own practice, and creating better professional development programs that will train teachers to deliver meaningful content in ways that lead to the highest possible student achievement.

WCER and the Standards

In the 1980s UW-Madison education professor Thomas A. Romberg helped direct educators and researchers in producing the document that was released in 1989 as the NCTM *Curriculum Standards*, out of which the *Focal Points* grew. WCER research has consistently taken these ideas as foundations for research in a number of research projects (see notes at end of this article). That is still the case today. Far from “turning back” or admitting to some “mistake,” NCTM and education researchers continue to draw attention to, and discover more about, best practices that lead to improved student learning, effective teaching, and better professional development.

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FROM THE DIRECTOR

Adam Gamoran

The Wisconsin Idea

WCER research addresses educational policy and practice nationwide. Three current initiatives involve particularly close work with policymakers and practitioners in our own state.

The **Value-Added Research Center (VARC)** works with the Wisconsin Department of Public Instruction (DPI) and the Milwaukee Public Schools to find more sophisticated and meaningful ways to evaluate the effectiveness of schools, teachers, and educational programs and policies. VARC works with DPI staff and the Milwaukee Public Schools as they create integrated resource information systems to assess student, teacher, classroom, and school effects on value-added student learning gains, and to connect resources at the school, classroom, and student levels to effectiveness in improving student learning.

WCER's **CPRE** director Allan Odden is leading a collaboration with the chairs of the State Senate and Assembly Education Committees, superintendents of the Milwaukee Public Schools and Madison Metropolitan Schools, teachers, and business representatives to determine what is an 'adequate' level of spending on education for an average child in Wisconsin. By "adequate" they mean to identify the programs and financial resources needed to attain the state's curricular standards and performance standards. They're addressing the recommendation of the Governor's Task Force on Educational Excellence, which aims to build a statewide consensus on what constitutes an adequate education.

WCER's **SCALE** project is a national network of more than 50 working groups of educators and researchers focused on improving mathematics and science teaching and learning at all levels. One of SCALE's institutional partners is our own Madison Metropolitan School District, the second largest district in the state. It serves nearly 25,000 students, 36% of whom come from low-income families, and 12% of whom are classified as Limited English Proficient. This past spring, SCALE principal investigator Terry Millar received a MMSD Distinguished Service Award for his contributions to the district's Math Masters Program and for his role in the submission of a successful National Science Foundation proposal, the K-Through-Infinity (KTI) Professional Development Partnership.

As part of the University of Wisconsin, WCER contributes to the "**Wisconsin Idea**," a tradition first stated by UW President Charles Van Hise in 1904. Van Hise declared that he would "never be content until the beneficent influence of the university reaches every family in the state." Today that belief fosters close working relationships within the state, throughout the country, and around the world.

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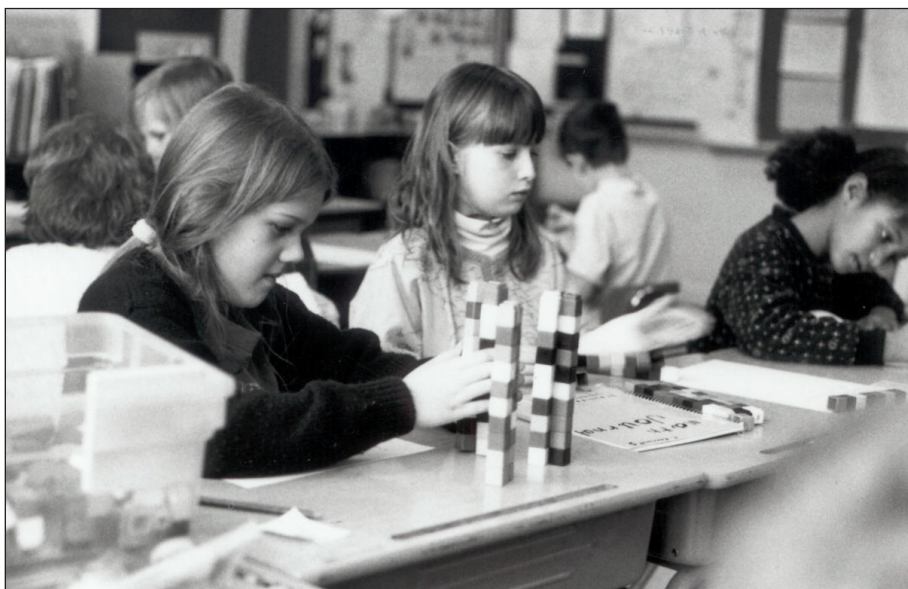
As an example, researchers in WCER's interdisciplinary STAAR project (*Supporting the Transition from Arithmetic to Algebraic Reasoning*) study middle grade students' transition from arithmetic into algebraic reasoning. Given the complexity of this topic, the research progresses along three parallel lines of study. At the student level, the research drills down to core algebraic concepts including students' understanding of equivalence, variable, and representational fluency. Knowing what the equals sign means seems fairly obvious, but students often misinterpret it, and that affects their ability to learn. At the teaching level, STAAR research investigates teachers' knowledge and beliefs about their own practices. Teachers are humans, and they enter the classrooms with some preconceptions and biases. It's important to know how those affect student learning, and this project measures those effects. And third, on the level of professional development, the project builds on cumulative insights from the other two levels to help teachers recognize students' algebraic thinking patterns and to recognize opportunities to foster better mathematical thinking.

WCER researchers Martha Alibali, Pam Asquith, Sharon Derry, Eric Knuth, and Mitchell Nathan are part of the interdisciplinary STAAR team that includes experts in developmental psychology, educational psychology, technology and learning environment design, teaching and teacher education, research methods, and program evaluation. Here are some of their current areas of focus.

Student understanding

Equivalence. STAAR research has found that many students misunderstand what the equals sign means. They often think it is a command to "process something," rather than showing a relationship between two sets of values. This misconception interferes with students' ability to solve equations. Improving students' understanding of the equal sign, and their preparation for algebra, may require changes in teachers' instructional practices as well as changes in elementary and middle school mathematics curricula. For example, teachers can present students with statements of equality in different contexts besides the traditional presentation of operations on the left side of the equal sign and the "answer" to the right of it to further develop students' notions of equivalence.

Variable. STAAR research investigates the meanings middle school students assign to symbols used as variables, and how these perceptions change over time. As students move through the middle grades they come to understand that a symbol can stand for multiple values.



Students' representational fluency is their ability to solve problems using tables, graphs, words, or symbolic representations, and then to translate among these representations.

For example, in the expression $2n + 3$, students' thinking about the symbol progresses from the misconception that n can stand for a single digit only, to an understanding that n can stand for any number.

Representational fluency is students' ability to solve problems using tables, graphs, words, or symbolic representations, and then to translate among these representations. STAAR research looks at how middle school students use graphs to reason about and generalize patterns, with a focus on their speech and gestures. Verbal representations seem to be an effective way for students to learn to reason about patterns algebraically. Teachers and curriculum developers may want to hold back on combining representations for beginning students, as they appear to be most suitable for the most advanced students.

Teacher practice and professional development

STAAR research goes beyond studying students' development to include teachers' knowledge, instructional practices, and continuing professional development. For example, what kinds of teacher feedback best helps students repair their mathematical errors? The study has found "mitigated" negative feedback works best: The teacher avoids overtly indicating students' erroneous answers (to avoid a loss of face for the student) but rather uses confirmation checks, clarification requests, inviting other learners' ideas, and repetition of the student's inaccurate utterances. Combining two or more forms of feedback was the most effective way to help students repair their math errors.

STAAR research has found that in some cases teachers did not accurately predict students' understanding of the equals sign, but in terms of variables, teachers' knowledge about students' algebraic reasoning usually does accurately predict students' responses to written assessments.

STAAR research is exploring two models of professional development for middle school algebra teachers, both aimed at helping teachers promote algebraic thinking in their classrooms. One model, developed by colleagues at the

University of Colorado-Boulder, has been implemented with teachers in Colorado. It includes a summer institute and ongoing monthly professional development workshops. The other model, developed by the WCER research team, has been implemented with teachers located in Wisconsin. The program was the first offering of a permanent 3-credit graduate course that will include a summer workshop and monthly workshops during the school year.

A more constructive discussion

This continuing research into teacher professional development and teachers' thinking about student reasoning all comes down to improving student achievement in algebra, in particular, and mathematics, in general.

But too often popular discussions about mathematics education are reduced to the curriculum itself, and editorials offer a false choice between "the basics" on one hand, or "fuzzy math" on the other. In reality, there is no "math wars," except in the minds of some commentators. And to portray mathematics reform during the 1990s as "a torrent of misguided methods and confusing content" that left behind "flood debris" is simply irresponsible. It does nothing to promote productive public discourse about education reform. Parents, reporters, editors, and policymakers help students most when they consider how different the world will look when today's students enter their careers, what they'd like them to be able to do in that world, and how education can best get them there.



The STAAR Project is a grant funded by the Interagency Education Research Initiative (IERI).

WCER is home to a number of mathematics research projects. For a list of all current projects see http://www.wcer.wisc.edu/projects/index.php?_topic=all&_view=noarchive ; for a list of findings from completed projects see http://www.wcer.wisc.edu/articleindex/index.php?req=show_subcat&cat_id=6&parent_id=0

What is CSR?

Comprehensive School Reform (CSR) means using proven strategies to improve the school as a whole, instead of piecemeal reforms that are common in education. CSR builds on state and local efforts to connect higher standards and school improvement by helping to fund the initial implementation of reforms that are coordinated with, and sustained by, all the resources available to the school, including federal, state, local and private resources. The goal is to enable all children, including children from low-income families, children with limited English proficiency, and children with disabilities, to reach challenging academic standards.

Taking Reform to Scale

The federal government's continued support of replicable, research-based educational programs, funded through Title I and other national policies, could revolutionize school improvement in some of the most challenging contexts, says UW-Madison education professor Geoffrey Borman.

Across varying contexts, Direct Instruction, the Comer School Development Program, and Success for All have shown robust results and have shown that, in general, they can be expected to improve students' test scores. These three models stand out from other available comprehensive school reform (CSR) designs by the quantity and generalizability of their outcomes, the reliable positive effects on student achievement, and the overall quality of the evidence.

Borman says perhaps the most striking theme of his recent study of Title I and CSR results is the wide variety in overall effects of these national efforts to bring reform to high-poverty schools. Each of the 29 CSR programs offers a distinctive and replicable model of school reform, but the successes schools experience depend upon how well they "buy into" and sustain the tenets of the various approaches. In other words, implementation matters.

Borman's meta-analysis did find limitations in quality and quantity of studies supporting the effects of CSR and Title I. For example, despite annual governmental expenditures of approximately \$10 billion and a history of nearly 40 years, Title I itself has never been subjected to randomized trials. There have been large-scale evaluations of Title I, but they typically have provided nationally representative survey data describing the characteristics of Title I and non-Title I schools, the characteristics of Title I and non-Title I students, and the achievement outcomes of participants and non-participants.

Quasi-experimental comparisons of outcomes among Title I and non-Title I students have provided some insights into the

potential achievement effects of the program, Borman says. But he urges researchers to spend less time attempting to generate national estimates of the program's characteristics and effectiveness, and more time on studying the effectiveness of specific interventions that could be funded under Title I.

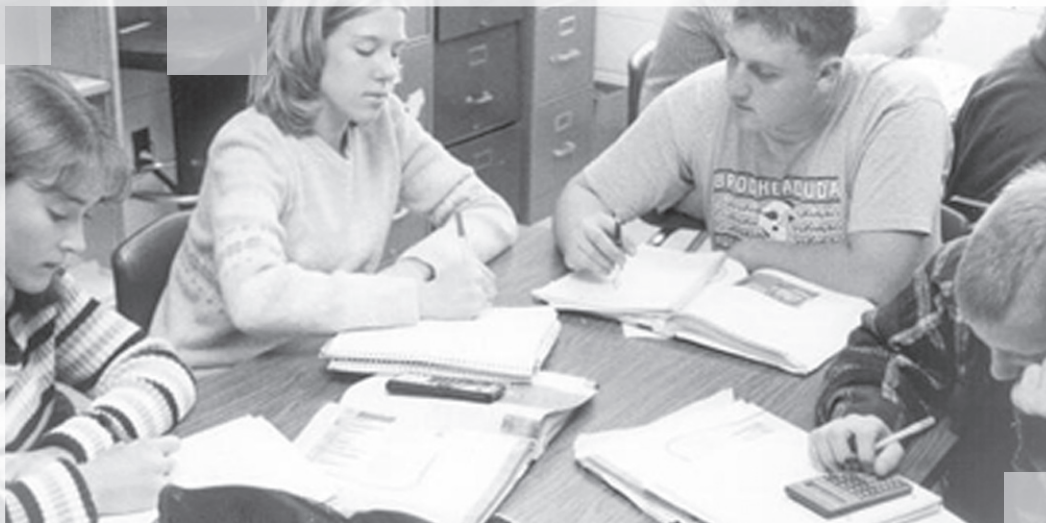
When it comes to implementing clear and replicable strategies for school change, policy mandates—even with local flexibility—are less likely to produce educational reform and improved student achievement than provider-based assistance. Although his study found that clearer federal mandates were associated with improved implementation and effects of Title I, these efforts produced only modest effects on student achievement outcomes.

In contrast, the most successful CSR models have enjoyed sustained periods of development, evaluation, and refinement. They provide clear and replicable strategies for reforming schools. Despite being known as "comprehensive" models, Success for All, Direct Instruction, and the Comer School Development Program focus on improvement in one core area: literacy instruction. These clear, focused, and well-supported school-based models of improvement are in stark contrast to top-down direction and flexibility for educational reform.

The results from national efforts suggest that large-scale reform can produce widespread, but modest, achievement effects. But better evidence is needed to provide both summative and formative appraisals of current and future national efforts to scale up reform in high-poverty schools. Rather than approving CSR programs on the basis of the 11 federal requirements (e.g., parent outreach program, clear goals and benchmarks) that make a model "comprehensive," schools and policymakers should pay even stronger attention to model outputs.



Adapted from "National Efforts to Bring Reform to Scale in High-Poverty Schools: Outcomes and Implications," *Review of Research in Education* (29) 2005, pp. 1-27.



Education for Innovation

Even before they graduate, some fortunate high school students become urban planners and redesign a popular downtown pedestrian mall. They work with a city budget plan and consider letters from concerned citizens about issues like crime, revenue, jobs, waste, traffic, and affordable housing. They conduct a site assessment, then use an interactive map of the downtown area to create a redevelopment plan. They balance the economic, social, and environmental costs and benefits of their proposals against those of alternative choices.

Welcome to Urban Science, one of several computer-based epistemic games developed by UW-Madison education professor David Williamson Shaffer and his graduate students. Epistemic games challenge players to learn to think as professionals and help prepare them for innovative thinking from the start. Thanks to games like Urban Science, students don't have to wait to begin their education for innovation until college, or graduate school, or their entry into the work force.

Unfortunately, most students in the U.S. today are still being prepared—in school, and at home—for “commodity jobs” like call-center operator, computer programmer, even engineer—that can be done more cheaply and just as efficiently outside the U.S. The world economy rewards people who can do innovative work and punishes those who can't. So why are students so rarely taught and challenged to think innovatively? American public schools spend considerable time teaching basic skills for standardized tests and less time teaching student to solve challenging problems and think in innovative ways. Research has shown for some time that many students who pass typical mathematics school tests can't actually apply their knowledge to solve problems.

Rather than first learning facts, information, and theories, and then trying to apply them, epistemic games challenge students to learn and remember the facts, information, and theories because they need them to play the game in the first place, to solve some real-world problem.

Epistemic games can transform education to meet the challenge of innovation in a global economy. Epistemic games are about knowledge, but they are not about memorizing facts. They are about *making* knowledge, *applying* knowledge, and *sharing* knowledge. Epistemic games are rigorous, motivating, and complex because that's what characterizes the professional training on which they are modeled.



For more examples of epistemic games see <http://epistemicgames.org/cgi-bin/coweb/eop.cgi?REQUEST=display&PAGE=5>

For links to papers on this and related topics see http://coweb.wcer.wisc.edu/cgi-bin/cv.cgi?REQUEST=show_embed&CAT=New

The book, *How Computer Games Help Children Learn* (David Williamson Shaffer, foreword by James Paul Gee) was published in December by Palgrave Macmillan.

Adapted from Shaffer, D. W., & Gee, J. P. (2005). "Before every child is left behind: How epistemic games can solve the coming crisis in education" (WCER Working Paper No. 2005-7): University of Wisconsin-Madison, Wisconsin Center for Education Research.



David Shaffer



Multiyear Summer School

The large and persistent achievement gap between minority poor students and white middle class students is an enduring national problem. But that can be changed. What children do during summer break has tremendous implications for understanding and addressing the achievement gap.

In a 3-year study of the Teach Baltimore Summer Academy, UW-Madison education professor Geoffrey Borman and colleagues measured how much a multiyear summer school program counteracts the cumulative effect of the “summer slide” on reading achievement of students from low-SES families—the drop in students’ performance that occurs over the summer.

The Teach Baltimore program enrolls students in kindergarten—before they have the opportunity to fall far behind. It offers disadvantaged students continuing opportunities, summer after summer. The summer slide has a disproportionate impact on children from low-SES families. Baltimore City public school students suffer a considerable disadvantage, where 86% of the students at Teach Baltimore sites were eligible for free and reduced-price lunch during the 1999-2000 school year, compared with 75% of the students in Baltimore City and only 35% of students across Maryland.

Baltimore students, like students from other urban centers, also perform at considerably lower academic levels. For example, only 15% of third-grade students at Teach Baltimore sites performed satisfactorily on the reading section of the Maryland School Performance Assessment Program (1999-2000), compared to 19% in Baltimore City and 39% statewide.

Using a randomized field trial, and selecting students from 10 high-poverty urban schools, Borman and colleagues studied the effectiveness of the summer learning program. The study compared a treatment group of 438 students to a no-treatment ‘control’ group of 248 children.

Consistent with previous research on the summer achievement slide, this study showed that essentially no learning – as measured by reading achievement tests – takes place over the summer for early elementary school students from high-poverty urban neighborhoods.

However, after the third year of the program, students who reliably attended each summer returned to school in the fall with achievement scores of approximately one-half of one standard deviation higher than those of their similar peers from a control group. This improvement translates into 50 percent of one grade level in vocabulary, 40 percent of one grade level in comprehension, and 41 percent of one grade level on total reading.

Long-term differences in student learning among enrolled students were associated with differences in parent education levels among families from within the high-poverty neighborhoods. Children from lower-SES families learned less across the 3-year period, and this disadvantage was explained by a combination of summer learning differences and school-year learning differences.

Although summer school programs can help prevent students from falling behind, the mere assignment of the students to the program is not enough. It’s important to encourage and sustain students’ long-term participation in the program across the 3 years. Maintaining contact with school personnel and with participating students and their parents likely helped improve attendance.

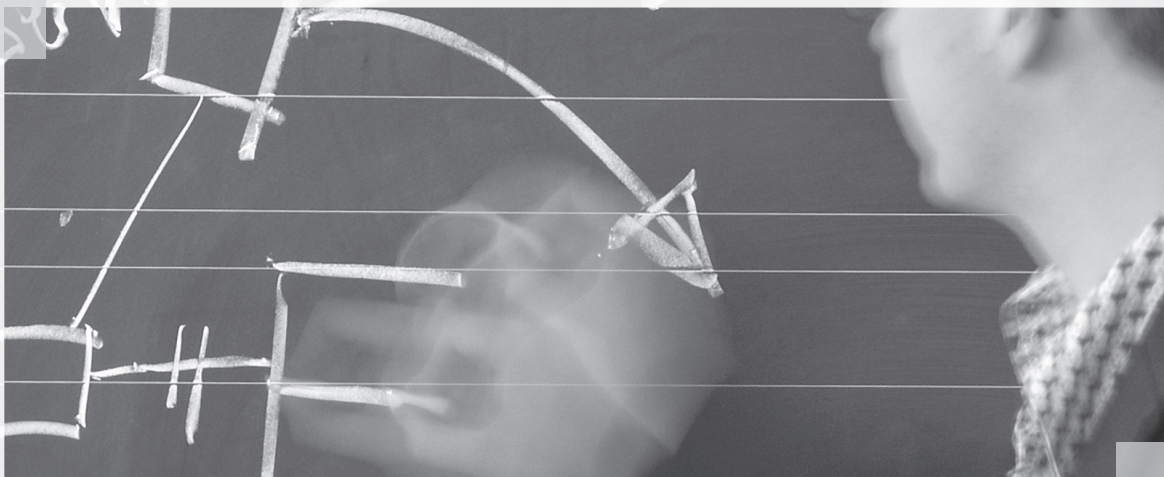
Aligning the content of the summer program with the regular school-year materials and instruction helped convince parents, teachers, and principals of the importance of the Summer Academy for students’ success during the school year. Weekly field trips and the daily recreational activities also seemed to maintain students’ interest.

Developing a better understanding of how parents and schools in high-poverty communities can work together to improve participation in summer school could prove to be a highly productive research and policy initiative for addressing the social inequalities associated with seasonal learning differences.



Funding provided by the Office of Educational Research and Improvement, U.S. Department of Education; Center for Research on the Education of Students Placed at Risk; the Smith Richardson Foundation, Children and Families at Risk Program; and the U.S. Department of Education Comprehensive Center VI.

Adapted from “Longitudinal Achievement Effects of Multiyear Summer School: Evidence From the Teach Baltimore Randomized Field Trial,” *Educational Evaluation and Policy Analysis*, Spring 2006, Vol. 28, No. 1, pp. 25-48.



The Real Issue of Performance Evaluation

When offering professional development services to teachers it may be more important to provide quality developmental assistance than to separate the summative (salary-related) evaluation from developmental (formative) evaluation.

Some have argued that splitting these two parts of teacher evaluation would help those evaluated to feel less defensive, more open to discussing performance problems, and more open to taking suggestions. The evaluator, in turn, would be free to help the teacher improve performance without also having to make a salary-sensitive administrative evaluation.

But according to a recent study by WCER researcher Tony Milanowski and colleagues, it doesn't always happen this way. In fact, their recent study found no major differences between two groups of new teachers—one evaluated in separate evaluation manner, and the other evaluated in combined manner—in terms of their openness to discussion of difficulties, their reception and acceptance of performance feedback, their stress, turnover, or performance improvement.

One group of teachers in the study received both summative evaluation and formative mentoring from a single person. Teachers in the other group received evaluation and mentoring from different people. Researchers found little support for the argument that a formative-only evaluator provides more useful assistance toward improving performance: Teacher performance observation ratings over time did not show a greater performance gain for the separate-evaluations group. Nor did separating the evaluations appear to lessen teacher stress or the rate of teacher turnover.

Whether or not to separate the evaluation roles is not the real issue. What's really important is the quality of developmental assistance, the credibility and accessibility of the mentor or mentor-evaluator, and the personal compatibility of the evaluator and evaluatee. Results from teacher interview and surveys suggest that many of these factors were present in relatively equal amounts in each group.



Milanowski explains that whichever approach is taken, organizations need to ensure that developmental evaluation and assistance actually happen. In this study, not all of the employees in either group actually received the level of developmental assistance program designers intended.

Interviews with evaluatees suggested some reasons why reactions to the summative evaluations were more negative in the split role group. First, many teachers in the split-role group

perceived a lack of communication with the summative evaluator. In an attempt to make the separation real and keep the workload of the summative evaluators within bounds, these evaluators were instructed not to give extensive developmental feedback or coaching. But many in the split-role group said it was unfair to be assessed without being given any developmental assistance. Some resented the teacher evaluators, describing them as cold, clinical, and uncaring.

Second, separating roles between evaluators raises a risk of disassociating mentoring activities from the performance standards used for summative evaluation. Third, separating roles may lead to more negative reactions to the summative evaluation process. In this study, reactions to the summative evaluation process were more negative in the split-role group.

Milanowski says a limitation of this study is the non-random assignment of teachers to the groups. It is possible that the groups were not equivalent on pre-existing differences in characteristics that may have influenced reactions to the different programs, such as ability, self-efficacy, openness to coaching, or feedback orientation. A second limitation concerns the generalizability of the results beyond new teachers. New teachers may be more open to feedback and more motivated to use it than their experienced colleagues. The new teachers in this study may also have been less threatened by summative evaluation, because as beginners they may have believed that they were not expected to perform perfectly.

CPRE research in teacher compensation and school finance is funded by grants from the U.S. Department of Education, the Carnegie Corporation, and private donors. Adapted from the paper, "Split Roles in Performance Evaluation: A Field Study Involving New Teachers."

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 Production Instructional Media Development Center

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.

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ISSN 1073-1822
 Vol. 18, No. 2
 FALL 2006

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