WCER Highlights

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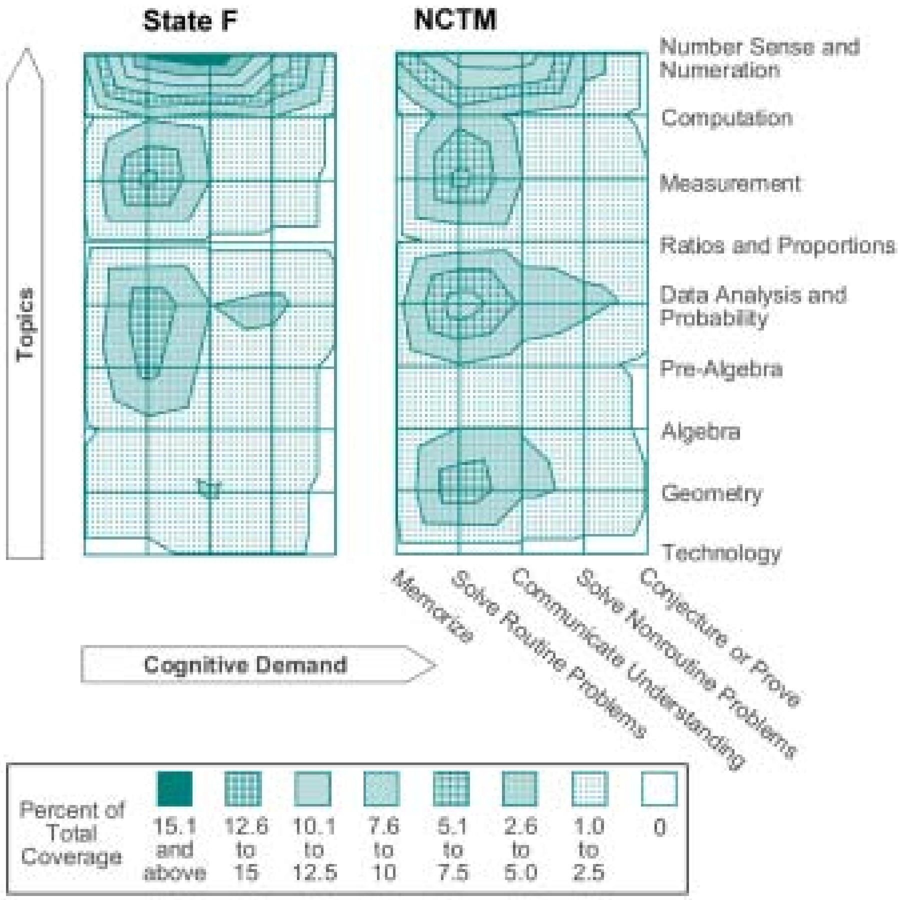
Measuring the content of instruction



Uniform content language allows one to compare alignment between states and to national standards.

Teachers get lots of advice and support from a variety of sources about what to teach. But do they really teach what is described in content standards? Do they teach what is in the textbook? Do they teach what is tested?

Classroom teachers are the ultimate arbiters of what is taught, and how. Regardless of what a state policy requires or what a district curriculum spells out, the classroom teacher ultimately decides how much time to allocate to particular school subjects, what topics to cover, when and in what order, to what standards of achievement, and to which students. Collectively, teachers' decisions, and their implementation, define the content of instruction.

Knowing what teachers actually teach is important to educators and policymakers who need to determine whether and to what degree there is overlap (or *alignment*) between what is taught, what is tested, and what national, state, and local content standards prescribe.

Tools for measuring content and alignment

For the past 25 years, Andrew Porter and his colleagues have studied teachers' content decision-making in mathematics and science. He has developed three kinds of tools for measuring content and alignment:

1. Teacher surveys describing the content of instruction;
2. Content analyses of instructional materials, including assessments; and
3. Indices of alignment between instructional content, instructional materials, and standards.

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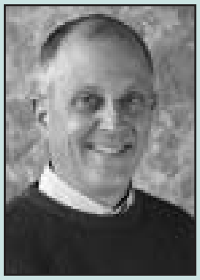
FROM THE DIRECTOR



Stimulating and measuring learning

For many years researchers have studied the development of children's algebraic reasoning and the nature of classroom interactions that support that development. Tom Carpenter and colleagues have found that, if young children are given the opportunity, they can make their own meaningful insights into the underlying structure and properties of arithmetic operations. They can also construct ways of representing them and justifying them.

Just as academic skills are crucial to students' success, so are academic enablers. Academic enablers include motivation, interpersonal skills, and engagement. Steve Elliott and Jim DiPerna maintain that these enabling attitudes should be taught explicitly to optimize students' learning.

Teachers are learners, too. Teacher professional change occurs through partnerships between university researchers and mathematics and science teachers. Adam Gamoran and colleagues recently explored how schools encouraged teacher collaboration through a combination of two elements: organic management and distributed leadership.

And finally, this issue contains an introduction to a measurement tool I developed with colleagues that can help educators develop content standards. The 'content matrix' aims to help educators make difficult choices about curriculum, instruction, and assessment. Policymakers can use the tool to build standards that clearly define what is to be taught and what is not to be taught.

For more information visit the WCER web site at www.wcer.wisc.edu

Andy Porter

The power of these tools lies in the uniform language they use for describing content. It is this uniform language that makes it possible to build indices of alignment.

The language developed by Porter and colleagues consists of uniform descriptors of topics (*level of coverage*) and student expectations (*categories of cognitive demand*). The level of coverage and the categories of cognitive demand form the columns and rows of a two-dimensional matrix. The content of instruction is described at the intersection between topic and cognitive demand (See Table I, *Content Matrix*).

The values placed in each cell of the matrix reflect data gathered from teacher surveys or from content analyses of students and other materials. For example, the surveys ask teachers to indicate, for the past school year,

1. the amount of time they devoted to each topic (the level of coverage), and
2. for each topic, the relative emphasis they gave to each student expectation (category of cognitive demand).

Porter and colleagues then analyze the results from surveys and content analyses to produce topographical maps that graphically display the content of instruction.

Porter's content matrix can also be used as a tool for developing content standards. The power of the content matrix in this context is that it facilitates clarity in making hard choices, Porter says. State content standards—and even national-level standards, like the mathematics standards developed by the National Council of Teachers of Mathematics (NCTM)—tend to include much more content than can be taught in depth. Educators and policymakers can use the content matrix (and the topographical maps displaying the content) to build standards that clearly define not only what is to be taught but also what is not to be taught.

Porter's method of measuring the content of instruction and alignment differs from other approaches in two ways:

1. The tools allow independent and replicable descriptions of the content of instructional practice and instructional materials. The uniform language for measuring content ensures descriptions at a consistent level of depth and specificity.
2. The uniform language allows alignment to be measured across a large number of instructional materials and instructional practices. See Fig. 1, *Vertical and horizontal alignment.*

Using the tools to study alignment

Most approaches to alignment of assessments with standards start with a particular state's standards and ask: to what extent does the content in those standards appear on the test? Such analyses are unique to each state. They don't allow comparisons between states or comparisons between state and other professional standards. But the uniform content language developed by Porter and colleagues allows one to compare alignment between states, and to national standards like the NCTM standards.

Rebecca Herman and Laura Desimone recently used Porter's tools to study the alignment of standards with assessments in four states. Their data showed that the assessment of each state was no more aligned to its own standards than to the standards of the other states or to those of NCTM.

Porter says that perhaps the state standards are not sufficiently specific to allow an assessment to be tightly aligned with them. But he says a more likely possibility is that states have much more

Topic	Category of cognitive demand				
	Memorize	Perform procedures	Communicate understanding	Solve nonroutine problems	Conjecture/ generalize/prove
Multiple-step equations					
Inequalities					
Linear equations					
Lines/slope and intercept					
Operations on polynomials					
Quadratic equations					

Table I. Content Matrix

work to do to bring their assessments into alignment with their standards. This finding is one about which U.S. Department of Education officials are expressing concern, Porter says.

The tools described here are used for science as well as mathematics. Some early work has also been done in the areas of reading and language arts and social studies. Following are examples of how the tools can be used to describe instructional practices, instructional materials, and alignment.

Describing instructional practices

Good measures of the content of instruction can serve

1. to define the process of teacher decision making in reaction to the various messages that teachers receive about what should be taught,
2. to describe the implemented curriculum or to measure the degree of implementation of a new curriculum,
3. to validate transcript studies, and
4. to provide the basis for powerful professional development experiences.

With regard to professional development, Andrew Porter and colleagues are using their measures of the content of instruction as the core of a new program on teachers' instructional practices, with funding from the National Science Foundation. The program begins by having teachers complete surveys describing the content of their instruction. Porter and colleagues then analyze the results and produce graphic displays that are returned to the teachers. Finally, teacher teams use the data to answer the following questions:

1. Is the content of our instruction what we want it to be? Is it aligned with our tests and content standards?
2. Are the differences in what teachers are teaching appropriate?
3. Do the prerequisite courses provide the content needed for effective grade-to-grade articulation?

In research, indices of alignment between the content of instruction and a student achievement test can be used as a control variable in studies of the effects of pedagogical practices on student achievement gains. An index of alignment can also be used as a descriptive variable in assessing the coherence of a state's or district's curriculum policy system.

For more information see Porter's page at the WCER Web site, www.wcer.wisc.edu.

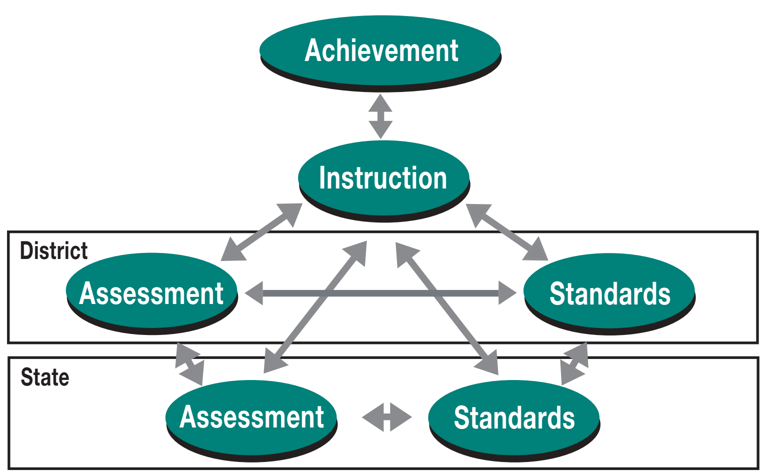


Figure 1. Vertical and horizontal alignment

"Academic enablers" critical to student success

Elliott

DiPerna

Malecki

Academic skills are, and should be, the primary focus of instruction in schools. However, recent research suggests that student achievement also depends on *academic enablers*. Academic enablers are attitudes and behaviors that allow a student to participate in, and ultimately benefit from, academic instruction in the classroom. These enablers include motivation, interpersonal skills, engagement, and study skills.

UW–Madison educational psychology professor Stephen N. Elliott and WCER researcher James DiPerna maintain that enabling skills and attitudes can, and should, be taught explicitly to optimize students' learning. Their recent research finds that students' prior achievement and interpersonal skills influence motivation, which, in turn, influences study skills and engagement to promote achievement.

Study skills begin to assume a significant role in promoting achievement as students advance through the elementary school curriculum. Beginning in the intermediate grade levels, there is a shift in curricular emphasis from learning to read to reading to learn. The curriculum increasingly emphasizes content acquisition over skill development. Thus study skills assume a more significant role in the learning process.

In a related study, Elliott and former student Christine Malecki (now a faculty member at Northern Illinois University) determined that interpersonal skills are a significant predictor of academic competence (the skills, attitudes, and behaviors that contribute to success); and academic competence, in turn, is a significant predictor of achievement. Elliott and Malecki concluded that social skills have a significant predictive relationship with academic outcomes.

There is more evidence to support the relationships between academic achievement and students' competence. This evidence comes from research using DiPerna and Elliott's Academic Competence Evaluation Scales (ACES). DiPerna and Elliott have found that academic enablers measured by ACES affect student grades and performance on standardized tests of achievement.

There are practical reasons for measuring academic enablers. School psychologists and other education professionals need a framework for thinking about assessment, intervention, and prevention services so they can help students receive optimal benefit from their education. Elliott points out that failing to address academic enablers may result in assessment and intervention plans that overlook key factors contributing to a student's academic difficulty.

Prior achievement is a strong predictor of current achievement (knowledge and skills). Likewise, current achievement is a strong predictor of future achievement. For students experiencing academic difficulty, chances for future academic success may be limited unless an educator intervenes to address specific problems. Delaying intervention to allow a students' skills to mature and possibly catch up to grade-level expectations may not be a wise choice, even for students at the primary level.

The DiPerna and Elliott study suggests that students' motivation, engagement, study skills, and interpersonal skills should be considered when designing assessments for students experiencing academic difficulty. For example, a practitioner who designs an assessment focusing exclusively on motivation and current academic skills may be overlooking important things that contribute to the student's academic performance (e.g., study skills, interpersonal skills). This omission could result in identifying the wrong cause of the academic difficulty. The educator also may develop an intervention that fails to address the true problem (e.g., difficulty getting along with others in class, which decreases a student's motivation to succeed in the classroom).

Since academic enablers contribute in meaningful ways to academic achievement, and the primary responsibility of schools and education professionals is to promote achievement, schools and educators need to consider what is being done to promote the development of academic enablers for all students.

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Research funding was provided by the Northeast Foundation for Children and the Fitchburg (Mass.) Public Schools.

Information for this article originally appeared in *School Psychology Review*, 2002, vol. 31, issue 3, pp. 298–312.

Putting case study results into context

Researchers studying schools as organizations often confront a tension between the need to achieve an in-depth understanding of local organizational conditions, on the one hand, and the need to know whether the knowledge gained from such case studies can be generalized more broadly, on the other.

Drawing on a national database helped WCER researchers Adam Gamoran and Tona Williams say more about how a school's organizational context can support teachers' efforts to improve their teaching.

Gamoran and Williams and their colleagues were concerned with how schools and school districts support teachers' efforts to improve their teaching. In their examination of cases of teacher change in Wisconsin and Massachusetts, they discovered that leadership and autonomy were important aspects of schools' organizational contexts that supported change. The question then became: Was the level of autonomy and leadership they found in these cases really significant, in a national context?

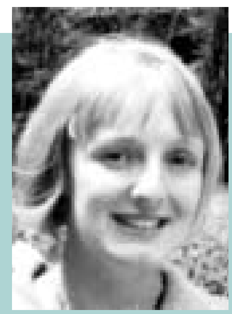
In two districts, Gamoran and Williams and their research team interviewed teachers, surveyed them, and observed them in professional development seminars. In these districts, teacher change occurred through partnerships between university researchers and mathematics and science teachers as they developed classroom practices of "teaching for understanding"—that is, attending to student thinking, focusing on powerful scientific and mathematical ideas and practices, and developing equitable classroom learning communities. Gamoran and Williams' study explored how the organizational context of each site affected collaboration to teach for understanding.

Gamoran and Williams found that the sites encouraged collaboration through a combination of two elements: organic management and distributed leadership. *Organic management* means that leaders respond to needs that emerge from teaching, instead of simply allocating resources in a bureaucratic manner. *Distributed leadership* takes advantage of expertise at all organizational levels and allows both teachers and administrators to make important decisions, instead of centralizing authority. These two practices enabled the schools to adapt to changes in teachers' thinking and classroom activities in ways that would not have been possible had the schools relied solely on more traditional school organization.

The study also found that administrators who adopted a style of organic management that responded to teacher initiatives faced two important tradeoffs: (a) when teachers were more autonomous, it was more difficult to establish a coherent direction for the school; and (b) when teachers provided their own leadership, it was more challenging to ensure the completion of routine administrative tasks. Across the sites, administrators adopted a range of strategies to address these tradeoffs.

In the cases studied, leadership in support of teacher change tended to focus either on establishing a compelling district vision that supported teaching for understanding or on providing teachers with the autonomy to develop their own visions. Each approach appeared to be effective. Gamoran and Williams also found that leaders most effectively supported change when they distributed authority beyond conventional leadership positions, while also finding ways to manage the necessary logistical details of professional development and other teacher improvement processes.

Gamoran



Williams

Comparison to national averages

Analysis of only two districts could not give Gamoran and Williams the perspective necessary to interpret the broader significance of their findings. Without knowledge of national averages for the factors they studied, Gamoran and Williams would have been limited to comparing the cases to one another and guessing about their overall importance. Therefore, when designing their survey, they drew most of the questions from the Schools and Staffing Survey (SASS) of the National Center for Education Statistics (NCES). This allowed them to compare their findings with national data. When applied systematically, such national-sample data sets can bridge macro-/micro-level, and qualitative/quantitative, gaps in education research.

In the case studies, Gamoran and Williams and their colleagues found that leaders in the Wisconsin site emphasized providing teachers the autonomy to establish their own visions, whereas leaders in the Massachusetts site developed a district-wide vision to overcome a prior lack of coherence among teachers and schools. In survey responses, compared to national averages, teachers in both states

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Developing algebraic reasoning in the elementary school

Effective teachers find instructional content that makes students' implicit knowledge explicit.

Children in elementary school mathematics classes are often able to do more than the current curriculum challenges them to do. For example, they can learn to generalize and to express their generalizations accurately using natural language and symbols. When they are given the opportunity, they learn to adapt their thinking about arithmetic so that it provides a stronger foundation for making the often difficult transition to learning algebra.

School mathematics curricula in the U.S. have traditionally separated arithmetic and algebra. This historic separation has deprived students of powerful schemes for thinking about mathematics in the early grades, says UW–Madison education professor Thomas Carpenter. Carpenter directs the National Center for Improving Student Learning and Achievement in Mathematics and Science (NCISLA).

Separating arithmetic and algebra makes it more difficult for students to learn algebra in the later grades. But simply pushing the current high school algebra curriculum down into the elementary school won't work. A broader conception of algebra emphasizes the development of algebraic thinking, rather than just skilled use of algebraic procedures. Students in the elementary grades can begin to engage in meaningful discussion about mathematical proof and make significant progress in understanding its nature and importance. Development of their algebraic reasoning is reflected in their ability to generate, represent, and justify generalizations about fundamental properties of arithmetic.

In their research, NCISLA researchers Tom Carpenter, Linda Levi, Patricia Berman, Jae-Meen Baek, Julie Koehler, and Margaret Pligge have found that when students working with mathematics make generalizations and represent them for their classmates, they articulate unifying ideas that make important mathematical relationships explicit. Underlying this pedagogical approach is a conception of mathematical understanding as constructing mathematical relationships and reflecting on and articulating those relationships.

For the last 5 years, Carpenter and his colleagues have worked intensively with a group of teachers to study the development of students' algebraic reasoning in the elementary grades and to construct instructional approaches that support that development. Their work with 100 elementary school teachers and their students in Grades 1 through 6, including in-depth studies of three classes, has provided the following insights.

A window on student thinking

When students make generalizations about properties of numbers or operations, they make explicit their mathematical thinking. Generalizations provide the class with fundamental mathematical propositions for examination, while also opening up students' thinking for analysis and discussion. Although students often have a great deal of implicit knowledge of properties of arithmetic operations, they typically have not explicitly examined generalizations about properties of numbers and operations or thought systematically about them. The trick for educators, says Carpenter, is to find an instructional context in which students' implicit knowledge can be made explicit. Discussion of appropriately selected true and false number sentences provides such a context.

As an example: In one class exercise, children were asked whether it is true that 0 + 5,869 = 5,869. After some discussion, the group came up with the generalization: "Zero added with another number equals that number." They also came up with the following generalizations: "Zero subtracted from another number equals that number," and "Any number minus the same number equals zero." In addition, one student came up with several related generalizations about multiplication.

True, false, and open number sentences provided a context in which these students could begin to convert their implicit understandings into explicit generalizations. Number sentences generated by the teacher provided the initial basis for drawing out generalizations. But once the classes started to talk about generalizations, making generalizations became a class norm, and students would propose generalizations on their own.

In most of the classes studied, students would write generalizations on sheets of paper and post them in some location in the room. When generalizations were difficult to state clearly in natural language, the students would use symbols to express the generalizations precisely. For example, students represented a conjecture about changing the order of numbers in addition as follows: For all numbers a and b, a + b = b + a.

A teacher records students' generalizations.

Conclusions

Elementary school students can learn to adapt their thinking about arithmetic so that it is more algebraic in nature. They can learn that the equal sign represents a relation, not a sign to carry out a calculation. They can learn to generalize and to express their generalizations accurately using natural language and symbols. Although not all students in the elementary grades will master mathematical proof, they can begin to engage in meaningful discussion about proof and make significant progress in understanding its nature and importance.

Understanding justification and proof takes years to develop. Although many sixth-grade students in a NCISLA case study were not yet able to generate proofs by themselves, most of them learned to recognize the limits of examples and the value of general arguments. They engaged in discussions of the nature of proof that made explicit important issues that most students never encounter at any point in their education. These experiences could provide a foundation for deepening these students' understanding of proof in the future.

"One of the things that was striking about the classes we worked in was that the students were engaged in sense making," says Linda Levi. "They thought that mathematics should make sense and that they could make sense of it. Students persisted for extended periods of time working on a problem, because they thought they should be able to figure it out."

All students benefit by engaging in the kinds of interactions that are required to make generalizations explicit, represent them accurately with natural language and symbols, and demonstrate that they are valid for all numbers. Learning to use precise language and communicate about mathematical ideas addresses not only an important goal of the mathematics curriculum, but also important issues of equity. The best students have always figured out how to derive generalizations and thereby make mathematics easier to learn and apply. Helping students make generalizations explicit gives *all* students access to powerful ideas of mathematics.

A new book is available, *Thinking Mathematically: Integrating Arithmetic & Algebra in Elementary School*, by Carpenter, Levi, and Megan Loef Franke (Heinemann, 2003).

For more information about research into mathematics education, see the NCISLA Web site at http://www.wcer.wisc.edu/NCISLA/.

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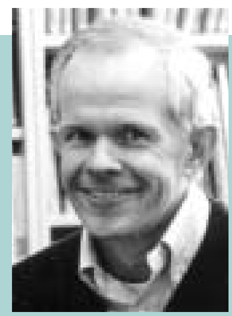

Carpenter

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Results

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reported higher levels of classroom autonomy and influence over school policy, which suggests the presence of distributed leadership. Teachers in the Wisconsin district reported a great deal of influence over the selection of instructional materials and teaching techniques, and an extraordinary level of influence over school policy. Massachusetts teachers, in contrast, scored lower on autonomy and influence. This pattern was consistent with interview responses from teachers, principals, and district staff that indicated the prominence of distributed leadership in the Wisconsin site, in particular.

At the same time, the Wisconsin and Massachusetts teachers both scored *below* national norms in the degree to which they perceived administrative personnel (and especially principals) as offering strong leadership and support. These findings, which suggest a lack of focus on centralized, top-down leadership, are consistent with Gamoran and Williams' interpretation that opening opportunities for teacher autonomy means reducing principals' vision-setting role.

Though Gamoran and Williams' study centered on developing an in-depth understanding of a small number of cases, the process of comparing some of their data against national norms made their analysis more robust.

For more information, contact Gamoran at gamoran@ssc.wisc.edu or Williams at twilliam@ssc.wisc.edu.

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