WCER Highlights

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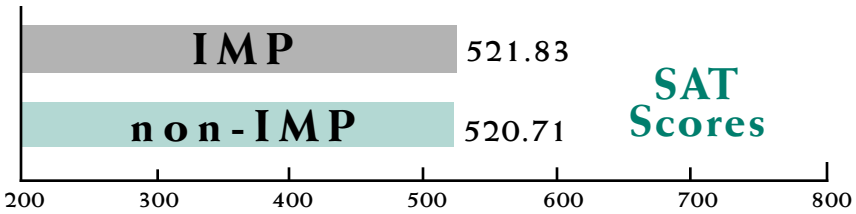
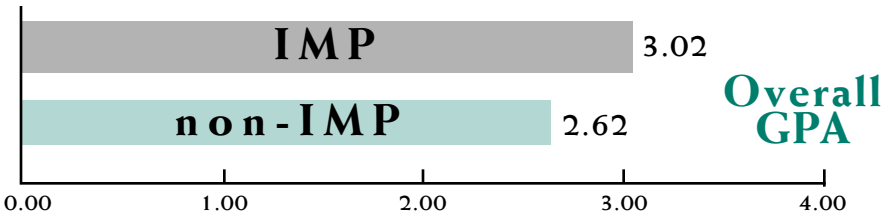
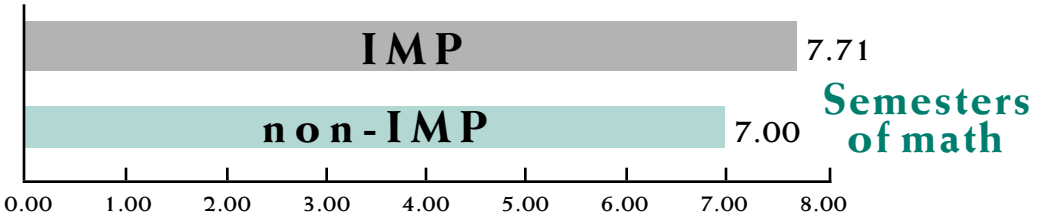
Mathematics curriculum boosts performance



Standard deviations for the groups were 114.75 (IMP) and 108.59 (non-IMP). The difference between groups is not statistically significant.



Standard deviations for the groups were .54 (IMP) and .59 (non-IMP). The difference between groups is statistically significant at the .01 level.



Standard deviations for the groups were .73 (IMP) and 1.58 (non-IMP). The difference between groups is statistically significant at the .01 level.

All tests of statistical significance are based on the z statistic.

WCER researcher Norman Webb found that students taking the Interactive Mathematics Program significantly outperformed their counterparts taking the traditional mathematics curriculum.

High school students taking an innovative mathematics curriculum significantly outperform their counterparts who take the traditional curriculum, according to studies conducted by WCER researcher Norman Webb and colleagues.

The Interactive Mathematics Program (IMP) integrates four years of high school mathematics that are traditionally presented as separate courses in algebra, geometry, trigonometry, and precalculus. IMP students also learn important concepts derived from probability and statistics. The curriculum meets college entrance requirements and aims to prepare students to use problem-solving skills at school and on the job.

IMP began as a response to a request for proposals from the California Postsecondary Education Commission in 1989; in 1996 the program was being used in more than 100 sites in 11 states. Webb and colleagues are conducting a five-year evaluation of the curriculum, examining:

WCER Highlights

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From the Director

Making sense of our world


JEFF MILLER

This issue of *Highlights* brings to your attention research and development on four efforts that are improving the quality and effectiveness of education.

Nearly every day we hear statistics mentioned in the news. We see stories illustrated with charts and graphs. But many adults aren't able to comprehend or evaluate these stories because they aren't knowledgeable about statistics. Researchers in our National Center for Research in Mathematical Sciences Education concluded that students need to begin learning statistics at an earlier age, that statistics should be integrated into the curriculum in imaginative ways, and that teachers need additional training to put this into practice.

Meanwhile, an innovative math curriculum known as the Interactive Mathematics Program (IMP) is helping high school students get better grades (in mathematics courses and overall) than their peers taking the traditional algebra sequence, according to WCER researcher Norman Webb and his team. IMP targets all students, including those who are at risk of leaving school before they have graduated, and groups of students who have traditionally been underrepresented in mathematics courses.

The National Institute for Science Education has won much praise over the past year for its Web site, *The Why Files,* which provides accurate, current information about science events in the news. To better understand how *The Why Files,* and the Web in general, can be used as teaching tools, NISE is studying how people navigate their way through the site.

Also in this issue you'll read that students with mild disabilities are demonstrating that they can handle performance assessments about as well as they handle more traditional multiple-choice tests. In a WCER study by Stephen Elliott and Thomas Kratochwill, students indicated that they generally found the performance assessment tasks interesting and useful in representing what they know.

For more information about this and other WCER research, visit our Web site at http://www.wcer.wisc.edu. If you use "gopher" client software, visit our gopher site at the University of Wisconsin–Madison, under News Releases/Announcements, Newsletters and Newspapers.

Andy Porter

- the long-term effects of IMP on students who have completed at least three years of the curriculum;
- the inservice needs of teachers who implement the program;
- the rate at which underrepresented students successfully complete three and four years of the curriculum; and
- the variations in implementation that are necessary to make the curriculum successful in specific situations.

IMP targets all students, including those who are at risk of leaving school before they have graduated, and groups of students who have traditionally been underrepresented in mathematics courses, including female, African-American, and Latino students. Because the program is problem-based rather than subject-based, IMP students learn how to define problems and conduct mathematical analyses using a variety of skills and approaches. Students learn to draw on more than one of the traditional subject areas at once.

Webb's research finds that IMP students seem to do about as well as, and, in some cases slightly better than, matched non-IMP students on the SAT (the students were matched by mean score and standard deviation on a pre-high school measure of mathematics achievement) and that IMP students get better grades overall and in mathematics courses than their peers.

Because IMP students spend substantial time learning statistics and other areas recommended by the NCTM *Standards* but not in the traditional curriculum, Webb and colleagues wanted to verify that students were learning in those areas. Webb's team used three instruments at different grade levels and at different sites. After controlling for differences in math achievement prior to entering high school, Webb found that the IMP students in all three studies significantly outperformed their counterparts from the traditional curriculum.

More students take more advanced mathematics

Webb's study compared information on the high school mathematics careers of IMP and non-IMP students by analyzing the transcripts of all students graduating in 1993 from the three high schools that began using the IMP curriculum in 1989. Researchers analyzed the transcripts of more than 1,000 students in three high schools, looking at variables such as number and kinds of mathematics courses taken, standardized test scores, and grade point averages, including how these outcomes were affected by race and gender. The study revealed that a higher percentage of IMP students took at least three years of college-preparatory mathematics than students enrolled in the traditional algebra-geometry-calculus sequence. This finding was true for both female and male students and for all ethnic groups of significant size, at each of the three schools in the study.

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Measuring the performance of students with disabilities

Many educators find performance assessments appealing. Unlike traditional multiple-choice or fill-in-the-blanks tests, performance assessments require students to *create* an answer or product that demonstrates their knowledge or skills, rather than simply selecting a response. In performance assessment, students might be asked to conduct an experiment, write an extended essay, or solve a complex mathematical problem that involves the completion of multiple interrelated steps.

More than 40 states use, or are developing, large-scale performance assessments as part of their educational accountability programs. But the effects of large-scale performance assessments are relatively unknown, in particular for students who may be educationally at risk and for students with disabilities. Whether they are learning disabled, emotionally disabled, hearing handicapped, speech/language handicapped, or multiply handicapped, all students should be included in statewide and national programs of assessment. Yet 40 percent to 50 percent of school-age students with disabilities are excluded, because schools waive them out, because some students request not to be involved due to their disability, or because parents and teachers want students to avoid another failure experience.

UW–Madison Education Professors Stephen N. Elliott and Thomas R. Kratochwill believe that students with disabilities should participate in performance assessments, for a number of reasons:

- Their participation provides for a more accurate measure of how all students are performing in the system;
- Assessment programs are part of a "normalization" experience; and
- If students with disabilities don't participate, adaptations to assessment methods will be delayed.

Elliott and Kratochwill have found that students with mild disabilities can meaningfully participate in statewide, on-demand performance assessments with minimal accommodations. In a recent study, students with mild disabilities demonstrated that they could handle performance assessments about as well as they do more traditional multiple-choice tests. The students said that they generally found the performance assessment tasks more interesting and useful in representing what they know.

During the 1993–94 school year, Elliott and Kratochwill studied the use of performance assessment tasks in Wisconsin, coordinating their investigation with the Wisconsin Student Assessment System's Performance Assessment Development project, then based at WCER. The participating 184 students had varying academic abilities. They attended elementary, middle, and high schools. Half the participants had disabilities, and some accommodations were made for them; for example, use of a computer to type, assistance in reading instructions, use of an interpreter for students who are hearing impaired, assistance by a special education teacher, completion of the test in a resource room, increasing the amount of time to finish a task, or the use of one-on-one instruction for a Language Arts task.

The Language Arts performance assessment required students to read and think about selected passages, to discuss them in the course of whole-classroom and small-group discussions, to write for a variety of audiences and purposes, and to demonstrate their abilities to work together on a theme for several days. In each assessment instrument, students' work culminated in a written centerpiece. The mathematics assessments consisted of six to eight individual tasks per student. The tasks reflected educational objectives defined by the National Council of Teachers of Mathematics' *Curriculum and Evaluation Standards for School Mathematics*. Students used mathematics applications that involved reasoning, computing, and communicating.

The project team includes (front, left to right) Thomas Kratochwill and Stephen Elliott; (back) Christine Malecki, Ann Marquart, Aleta Gilbertson.

Assessments show what they can do

After students completed the tests, Elliott and Kratochwill interviewed 65 of them, 17 of whom had mild disabilities. Students said they found both the Math and Language Arts performance assessment tasks difficult, and nearly all students scored below the preliminary "proficiency" criteria described for the tasks. The average performances of the stu-

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Http://whyfiles.news.wisc.edu

The Pentagon says at least 5,000 veterans may have been exposed to chemical weapons during Operation Desert Storm. On Oct. 9, a report suggested the Gulf War syndrome may not even exist. What are some of the issues behind the mysterious ailment known as Gulf War syndrome? And what do we know about the agents of chemical warfare?

- The "Cool Science Image," updated weekly, allows *Why Files* visitors to see a volcano through the eye of a satellite, a comet through the eyepiece of a state-of-the-art telescope, or a developing fruit fly embryo through a microscope. Images have included electron scanning microscope images of blood cells, crystals, bread mold, nerve cells, and velcro!

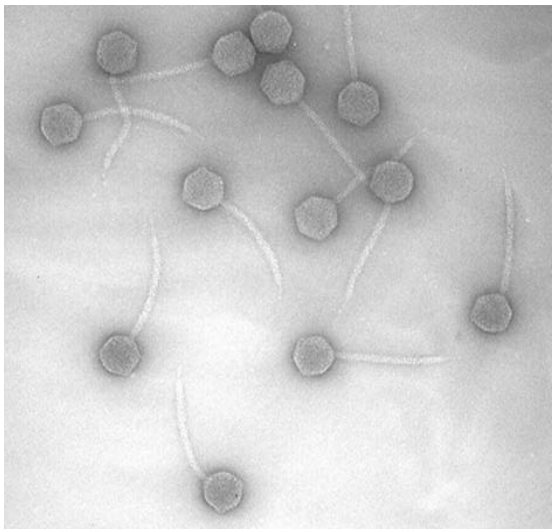
- In *The Why Files* Forum, anyone can discuss current science or technology events or the issues that drive science. Discussion topic areas include Astronomy, Biology/Chemistry, Physics/Math, The Earth, and Plants, Animals, and Humans. Post a message or a query!

The Why Files site has garnered many citations, including a "Top 25" Reference Site by *PC Magazine*, Microsoft Network's "Pick of the Day," a "Top Five" web pick by the National Center for Supercomputing Applications at the University of Illinois, an InfiNet "Cool Site of the Day," and a Netscape "Cool Site" pick, an honor that instantly doubled daily visits.

That's what World Wide Web users read recently on the home page of *The Why Files*, a site sponsored by the National Institute for Science Education (NISE). Established in 1995 with funding from the National Science Foundation, the NISE is a national center for the study of improving science, math, engineering, and technology education, from kindergarten through college and adulthood.

During a typical week, about 25,000 visitors access *The Why Files* Web site; find it at http://whyfiles.news.wisc.edu. They live in 60 countries and they download 71,343 pages of information—535,865 kilobytes of data. (When you visit, remember that the site's busiest day is Tuesday, and the busiest hours are between 9 a.m. and 4 p.m. CST.)

The Why Files serves as a combination public service, outreach tool, and teacher gathering place. Susan Trebach, Director of the UW–Madison Office of News and Public Affairs, says, "We developed *The Why Files* to provide convenient and free access to accurate, readable information about science events that touch nearly everyone. The site uses current news as an opportunity to teach." Visitors find that the information is layered, so they can access increasing detail and technical information. A new *Why Files* feature package on a topic in the news—everything from mosquitoes to tornadoes to the Unabomber, for example—is posted every two weeks.



A "cool science image." These viruses attach to a specific site on a bacterial cell wall, then squirt DNA into the host bacterium. Photo courtesy of the UW–Madison Institute for Molecular Virology.

"Nearly every day we hear news involving science: natural disasters, and new technology designed to treat disease, battle the elements, understand the unknown, or influence our fellow human beings," says Trebach. "And lurking behind the news of a passing comet or an epidemic is a wealth of fascinating information that is just as important as news of an event itself. But because of the limitations of time and space it never surfaces in the news of the day." As of this writing, the feature topic discussed heart surgery (because of the news on Yeltsin's surgery). Look for stories on genetically engineered crops, which were introduced widely for the first time in 1996, a mathematics-statistics story, a big-animal story, and more health stories.

Having quick access to scientific information that's relevant and useful will help students, parents, and teachers, says NISE co-director Andrew C. Porter. "*The Why Files* may be especially important for children and schools," he says. "We're ready to roll the information highway up to the schoolhouse door, but what's out there on the highway? We need quality *content*. We want to know how it is used, and to what effect."

The Why Files attempts to make science more accessible and meaningful, says Porter. "Our society has done a pretty good job over the years of

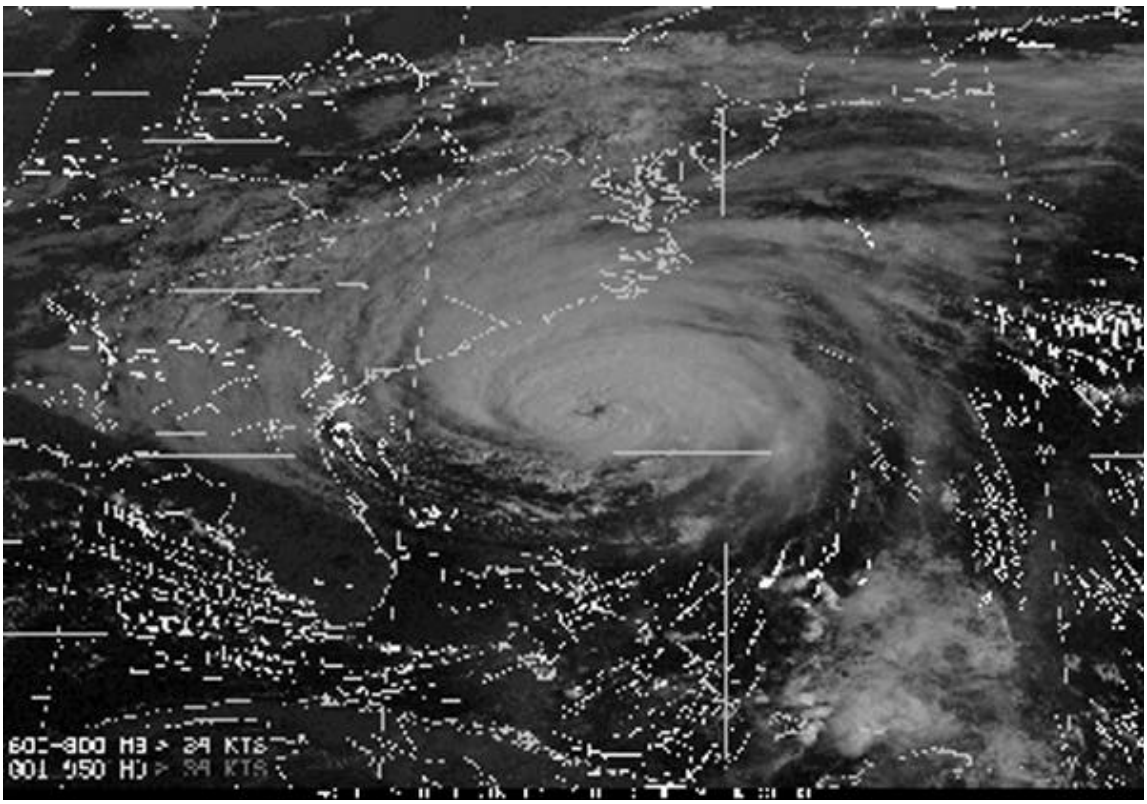
erecting walls between science and the public. If we're to survive and prosper, we need to knock some of those walls down so more people, especially young people, can participate. Using the Web may be one way to do that."

The Web as a teaching tool

The site was also developed to provide a context for investigating how the Web can be used to promote scientific literacy. *The Why Files* has served millions of requests for text and image files, but exactly *how* do people use *The Why Files*? Do they skip around randomly? Do they follow one idea in depth, taking side tracks that more fully illustrate a point? And how do people use the World Wide Web for research? NISE's Sharon Dunwoody, a UW–Madison Professor of Journalism and Environmental Studies, says there's virtually no literature on using the Web as a teaching tool. "We don't even have reliable estimates of how many people have access to the Internet. The Web is such a new tool that there's little information on the efficiency of its use for mass audience communication. There's even less information on using the technology to communicate science concepts."

To help fill this knowledge gap, Dunwoody and colleagues are addressing these questions: How can educators use the Web to enhance science, mathematics, engineering, and technology (SMET) literacy in diverse audiences? What proportion of visitors skim by a site versus genuinely engaging themselves in the process of being informed? Can we categorize visitors based on their levels of involvement with the site's information? How might such categorization lead to improvement in the design and content of a Web site? Is a Web site a communication channel that can effectively empower people to learn and use SMET-related information in their daily lives?

As more and more people use the Web, answering such questions becomes increasingly important. What's learned about people's use of *The Why Files* may eventually help other teaching sites become more effective. For more information, visit *The Why Files* at http://whyfiles.news.wisc.edu.



Another cool science image: Hurricane Fran, as seen through the eye of the National Oceanic and Atmospheric Administration's GOES 8 satellite, nears the southeastern United States. Picture courtesy of the Space Science and Engineering Center at the UW–Madison.

Coming up with statistics

Most adults in our society are not proficient at using statistics or probability to reason about important societal issues. Understanding the world requires knowing how to be critical of claims and arguments that are based on data and to interpret displays of information. Unfortunately, few activities that involve statistics are now carried out in K–12 mathematics classrooms. Some higher education students do not understand elementary statistical concepts even after completing several courses. To function as literate adults, students need to learn to use statistics.

For the past five years, researchers at WCER's National Center for Research in Mathematical Sciences Education (NCRMSE) have studied ways in which statistical content can best be integrated into the school mathematics curriculum. With funding from the U.S. Education Department's Office of Educational Research and Improvement, NCRMSE Director Thomas Romberg initiated the Working Group on Learning and Teaching Statistics in 1993.* Susanne Lajoie of McGill University chaired the group and UW–Madison Education Professors Sharon Derry and Richard Lehrer served as principal investigators. The Working Group broke ground in several areas over the course of the project; here are some highlights.

- Lajoie and her colleagues at McGill University developed and tested a computer-based library of exemplary statistical tasks (text and video examples of student work) that increased student motivation and learning. The exemplars showed students both models of and criteria for average and above-average performance on sample problems. They make assessment criteria accessible and clear, so that students can use them as benchmarks for their own statistics performances.
- A three-year project on teaching probabilistic reasoning, conducted by researchers Sharon Derry and Joel Levin, developed into a course that has since been implemented as a standard part of the curriculum in UW–Madison's Educational Psychology Department, with funding from the National Science Foundation. Derry and Levin examined three Grade 7 and Grade 8 classrooms in science, mathematics, and social studies. They focused on how students used evidence to make decisions in activities that involved medical research and government legislation. In the activities, students participated in simulation games that placed them in one or more group roles. They used argumentation and other forms of evidence to defend their positions.
- NCRMSE researcher Joan Garfield produced a database including all of the written materials that group members have located or written themselves in the areas of statistics education and the assessment of statistical knowledge.
- Researchers Jeff Horvath, Richard Lehrer, and Kathleen Metz found that primary grade students have five kinds of intuition on which instruction in statistics and probability can build. Primary grade students have intuitive knowledge of (1) relative magnitude, (2) part/whole relations, (3) uncertainty and indeterminacy, (4) the likelihood of an event, and (5) expected distributions of events. And in tests of statistics and probability units, middle school students showed they could use statistics to deal with data. Students collected information, judged the appropriateness of a sample of data, reasoned with that information, and drew conclusions from it. They developed useful and creative ways for dealing with information.

Getting teachers ready

Introducing statistics into the school curriculum presents several challenges, however. For example, many teachers have little or no background in statistics and probability. If teachers are to help their students learn and use statistical concepts, they will need in-depth staff development programs that focus on statistical content and on effective strategies for teaching it to K–12 students, according to working group members George Bright (University of North Carolina-Greensboro) and Susan Friel (University of North Carolina-Chapel Hill). Second, gathering, summarizing, and interpreting data in the classroom is time consuming and involves new kinds of teacher/student interactions.

But teachers *can* provide students with opportunities to do statistics in a manner that prepares them for real-world experiences. NCRMSE staff researchers Nancy LaVigne, Steve Munsie, and Tara Wilkie advocate a problem-solving approach to statistics that requires students to interpret the *meaning* of statistics, as opposed to simply understanding how to compute or generate statistics. In elemen-

* Growing out of the success of the NCRMSE, WCER's new School Mathematics and Science Achievement Center began in March 1996. SMSAC will create a set of principles for the design of classrooms that promote understanding in mathematics and science, grades kindergarten through high school. It will emphasize designing instructional innovations in teaching, curriculum, instructional technology, and assessments. It, too, is funded by Office of Educational Research and Improvement, U.S. Department of Education.

tary school, for example, teachers can link statistical understanding to number sense by having students collect data and sort, count, and measure interesting items. Once students make sense of these activities, they can then move on to work with graphs and tables. Such experiences help students understand how researchers collect and summarize data, and how to determine when flaws appear in a study's treatment of data or its conclusions.

How students' reasoning develops

To integrate statistics into the school mathematics curriculum in a meaningful way, teachers and researchers will need to continue developing and refining curricula to find a balance between the breadth and depth of content appropriate for students at the various grade levels. It may take several years, Lajoie says, to develop a solid research base from which to understand how students' reasoning in statistics and probability develops over time. "Although the statistics agenda is still open for exploration," she says, "different avenues have been explored, and only experience and research can tell us more about the appropriateness of our theoretical positions and our methodologies."

For more information, visit the NCRMSE archives on the University of Wisconsin–Madison gopher server under Newsletters and Other Special Interest Publications, or contact Lajoie at McGill University, Montreal, Canada (e-mail insl@musicb.mcgill.ca).

Assessments

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dents with disabilities were substantially lower (from $^1/_2$ to $^2/_3$ standard deviation) than those of students without disabilities. On some of the performance tasks, however, students with disabilities did as well as or better than students without disabilities.

Although they indicated lower satisfaction with the performance assessment tasks than their nondisabled cohort, the students with disabilities reported that the performance tests showed what they could do and said they were interesting to complete. Many students noted that they liked the content of the performance assessments, and that the content was similar to what they had been taught in class. Some students noted that a test like the performance assessment, involving their "pulling together" knowledge, would be better than more traditional multiple-choice tests at showing their abilities; a similar number of students noted that they felt a "recall" test or multiple-choice test was better.

Teachers said the performance assessment tasks were useful but difficult. They said that the accommodations provided were necessary for the success of students with disabilities. A few teachers mentioned that the performance assessment was overwhelming to some students with disabilities. However, one teacher noted that the students reached a "comfort level" with the assessment after some time.

Analyses comparing students' scores on the performance assessment tasks and on Wisconsin's multiple-choice Knowledge and Concepts test showed a moderate correlation (r = .36 to .68). Elliott explains: "This indicates that the two approaches to assessment capture some common skills; however, they also apparently assess some unique skills within similar subject matter domains."

"Given what we know now," Kratochwill says, "we recommend that results from performance assessments be conceptualized as supplemental to traditional assessment results when making decisions about students' learning skills and capabilities." He says that achievement and learning evidence resulting from performance assessments, particularly those that are aligned with a student's curriculum, appear to be relevant to accountability and general instructional interventions. "The growing interest in performance assessments shows many educators' desire to have assessments composed of tasks that they understand and that emphasize the application of knowledge," he says, adding that more research is needed to determine whether performance assessments can fulfill this goal.

The Elliott/Kratochwill study helps establish a set of performance assessment administration "guidelines" for students with disabilities. The information will help shape an agenda for future research on variables that students and teachers believe influence functioning on performance assessment tasks. For more information, contact Stephen Elliott at selliott@soemadison.wisc.edu, (608) 262–8841 or Thomas Kratochwill at tomkat@macc.wisc.edu, (608) 262–5912.

This study sheds light on how the academic performance of students with disabilities may be better assessed, what on-demand performance assessments may mean for these students, and what performance assessment may mean for educators interested in supporting such students.

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Math

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Among African-American students, 79 percent of those in the IMP program completed three years of college-preparatory mathematics, compared with 51 percent of African-American students in the algebra sequence. Comparable figures for Latino students were 80 percent for IMP students compared with 62 percent in the algebra sequence, and, for Caucasian students, 94 percent for IMP students compared with 82 percent for students in the algebra sequence, respectively.

Additionally, among students completing three years of college-preparatory mathematics, 71 percent of IMP students went on to complete an advanced mathematics course (mathematics analysis, trigonometry/analytic geometry, precalculus, or calculus), compared with 52 percent of students in the algebra sequence.

Project staff Peter Salkowski and Maritza Dowling discuss findings with director Norman Webb (right).

The finding that IMP students were more likely to take an advanced mathematics course was true at each of the three schools for both females and males and for each ethnic group of more than 20 students.

For more information about the curriculum itself, contact IMP, 6400 Hollis St., #5, Emeryville CA 94608 (510) 658–6400. For information about Webb's evaluation, contact him at normwebb@macc.wisc.edu or (608) 263–4287.

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