Effective teachers recognize that students bring different kinds of mathematical strengths into the classroom that can be used to raise students’ math competencies in formal schooling. Anita Wager, a UW–Madison professor in Curriculum and Instruction, points out that students learn mathematics more effectively when it connects to their lives outside of school.

Wager says educators must learn their students’ cultural and community mathematical practices and then connect these to what happens in school. She stresses that the way teachers translate or mathematize out-of-school practices needs to be meaningful. Otherwise classrooms will trivialize the mathematical ideas inherent in student’s home practices. To find out how teachers respond to this need to identify meaningful ways to incorporate out-of-school practices in mathematics classrooms, Wager studied a professional development seminar for elementary teachers. The study sought to determine (a) how teachers incorporated students’ out-of-school experiences in the mathematics classroom, and (b) the benefits and constraints of the various methods.

The semester-long professional development seminar focused on culturally relevant pedagogy. The seminar participants taught in three elementary schools that served diverse student bodies. Across the schools, 40% to 74% of students were from Native American, African American, Latino/a, and Hmong families. Of the students, 27% to 70% were eligible for free or reduced-price lunch.

During the ten three-hour seminar sessions, the participants read about the importance of children’s out-of-school mathematical practices and possibilities for culturally relevant pedagogy in the classroom. They designed surveys for students 8 to 10 years old to discover the types of mathematical activities in which students and their families participated. They then discussed how to build on these student practices.

Teachers then compared results of their own classroom surveys to those of their school
WCER has a decades-long tradition of investigating ways to improve mathematics instruction in K-12 classrooms. This issue of Research Highlights introduces two new developments in the field. Professor Eric Knuth says that helping more students succeed in algebra requires designing instruction not as an isolated course in eighth or ninth grade, but as a continuous strand spanning the entire K–12 curriculum. Knuth discusses how elementary school students can, and should, be introduced to important ideas of algebra in their study of arithmetic. And in her research, Professor Anita Wager works with teachers to discover, and build on, the different kinds of mathematical strengths students bring from their homes and cultures into the classroom. She shows how students learn mathematics more effectively when it connects to their lives outside of school.

Professor Aydin Bal studies how schools create supportive and predictable schoolwide social and academic environment. He discusses a practice called Culturally Responsive Positive Behavioral Interventions and Supports. CRPBIS helps educators develop a critical awareness of how they think about, and assess, student behavior and interaction. This practice emphasizes the social and academic benefits of creating common, shared understanding of desirable behaviors among members of school communities.

And finally we read about a computer simulation in which first-year engineering students learn about what engineers do in the work environment. In a game called Nephrotex students work for a virtual company that designs an ultrafiltration unit, or dialyzer. They must justify their design selections and explain why it meets stakeholders’ goals. Nephrotex is among a family of epistemic games developed at UW by a group led by professor David Williamson Shaffer.

FROM THE DIRECTOR

Adam Gamoran

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and the other schools to identify individual, classroom, and school differences. This activity prompted teachers to further explore their own students’ home, community, and cultural mathematical practices, as well as other ways to learn about their students. Teachers later taught, then reflected on, the lesson ideas they developed.

Wager’s study identified four practices that these teachers tried in their classrooms to draw from students’ cultural and out-of-school experiences.

**Using context**

The most common way the teachers linked school mathematics to students’ lives was to use student experience as the context for word problems and lessons. Two teachers, for example, were aware of several students’ interest in soccer. These two teachers created math word problems about measuring the area of a soccer field.

While it’s good that they attempted to connect real-world experience to the classroom, Wager notes that this example probably has limited effectiveness. Although several children may play or watch soccer, the mathematics they use relative to soccer likely does not include measuring the area of a soccer field.

**Mathematical practices linked to school**

Some teachers identified an out-of-school activity that required mathematics and then matched it to a math activity in school. For example, one teacher knew of a Hmong student’s practice of regularly helping her grandmother make “story cloths.” Seizing upon what she viewed as a cultural practice, the teacher attempted to relate that activity to school mathematics by discussing measurements that might be required to make story cloths.

Wager says it was unclear whether the strategies the child used for measuring story cloths differed from strategies the child learned in school. To link this practice to school math effectively, the teacher would need to learn the unique ways the child and her grandmother used measurement while making the story cloths.

**Embedded mathematical practices**

Embedded practices refer to situations in which a particular context drives the mathematics. In these situations, students develop informal strategies to accomplish a real-world task. These often differ substantially from the mathematical strategies typically taught in school. To identify these informal strategies, teachers need to observe them or ask the students to replicate the practice and explain their strategies. For example, one teacher asked students how they

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Students Learn to Represent Mathematical Unknowns

Algebra often serves as a gateway to higher mathematics, which is necessary for careers in science, technology, and engineering. Unfortunately many students are stopped at that gateway because they fail the course.

Failing to pass high school algebra can lead to life-altering consequences, including reduced lifetime earnings. A professor in UW–Madison’s Department of Curriculum and Instruction, Eric Knuth helps students understand algebra. In particular, he studies how students develop increasingly more sophisticated ways of thinking mathematically. Students’ mathematical practices involve learning to talk about problem solving, making claims about solutions, and justifying those claims, as well as using algebraic representations to model and solve problems.

Helping more students pass through the algebra gateway requires designing algebra education not as an isolated course in eighth or ninth grade, but as a continuous strand spanning grades kindergarten through high school. Knuth says elementary school students can, and should, be introduced to important ideas of algebra in their study of arithmetic.

Representing Variables with Letters

One of the challenges facing young mathematics students is learning how to use letters as variables to represent unknown quantities. Knuth and his research colleagues developed an Early Algebra Learning Progression (EALP) organized around that skill and four other “big ideas” in math instruction: generalized arithmetic; mathematical equivalence; functional thinking; and proportional reasoning.

To measure the effectiveness of the EALP, Knuth and colleagues studied 301 students in grades 3–5 from two elementary schools. In six classrooms students received an early algebra intervention, and in 10 classrooms they did not. These latter classrooms served as the control group in the experiment.

The experimental classrooms participated in an EALP-based curriculum for approximately 1 hour each week for the majority of the school year. Students took a pretest in early September, before the start of the teaching intervention. A mid-year review was administered in late November, after eight intervention lessons. The students in the experimental classrooms worked in groups on tasks designed to encourage them to reason algebraically in a variety of ways and to justify their thinking to themselves and their classmates. One exercise was called The Silly Bands Task (see above).

At the beginning of the intervention, students responding to the question of how they would represent Jackson’s number of silly bands demonstrated no prior knowledge of how to represent an unknown quantity using variables. They preferred to assign specific values. Students initially struggled to produce correct representations or descriptions of the unknown quantities in the problem. Some students did produce a correct representation or description, but none of them used variables to represent the unknown. By the time of the mid-year assessment, however, at least 75% of students at all grade levels attempted to represent the unknown quantities using a variable, and most did so correctly.

Conclusion

Initially, students exhibited great difficulty representing unknown quantities in a general way (i.e., without assigning a specific value). Yet, after 8 weeks the majority of students seemed to be using variables in meaningful ways that were unknown to them at the start of the school year. Knuth does not advocate shifting traditional instruction in symbol manipulation to earlier grades. Rather, he calls for broadening the notion of what it means to think algebraically. As his study shows, even elementary school students can grasp important ideas of algebra.

More about Knuth’s research: http://ci.education.wisc.edu/ci/people/faculty/eric-knuth

Eric Knuth
Some first-year engineering students at UW-Madison this fall will participate in a virtual internship to learn about biomedical engineering. New research suggests that participating in a virtual internship increases students’ interest in engineering and their desire to pursue an engineering degree. This effect is especially pronounced among women.

Using the computer simulation, students become interns at the fictitious company Nephrotex. Their task is to design a nanotechnology-based membrane for use in hemodialysis machines. These machines filter the blood of patients with kidney disorders. Students work both individually and in small project teams. A faculty member or teaching assistant guides them via in-game e-mail and chat.

The virtual environment prompts students to learn more about the company’s mission, vision, and history. After students design, build, and test prototypes, they select the one they think will best satisfy the company stakeholders, who have conflicting expectations and values. Complex problem solving is required of the students, as it is not possible to create a device that satisfies all of the stakeholders’ demands. Each student must individually justify his or her design selection and explain why it meets the criteria of certain stakeholders and not others.

Nephrotex is one of a number of epistemic games developed at UW by a group of investigators, researchers, and students led by David Williamson Shaffer, a professor in the Department of Educational Psychology and a learning scientist at WCER.

Shaffer says Nephrotex offers an alternative first-year program that models authentic engineering practices and motivates students, especially women and underrepresented minorities, to continue in the field of engineering. Although women make up an increasing portion of undergraduate students in the United States, their numbers in engineering are declining.

Designing the Simulation

The initial design, development, and testing of Nephrotex involved faculty, graduate students, and undergraduates from the UW–Madison College of Engineering and the School of Education. Initial funding was provided by a grant from the National Science Foundation. To study its effectiveness, Nephrotex was offered as an elective module in a first-year engineering course. Data were gathered on (1) students’ perceptions of engineering careers and their motivation to persist in engineering, and (2) students’ discourse as they participated in the game.

Evaluators measured how students developed connections among the skills, knowledge, identity, and values of professional engineering practice. These measurements helped determine the extent to which students were designing and problem-solving in ways similar to a professional engineer.

A new assessment tool, Epistemic Network Analysis (ENA), was developed by the Epistemic Games Group to measure learning and complex thinking in such settings. Standardized assessments measure whether a student possesses certain knowledge or skills. ENA, in contrast, assesses how students make connections between knowledge, skills, values, identity, and ways of making decisions. Measuring these connections provides a much more detailed and accurate representation of complex thinking. Complex thinking involves understanding how different elements of problem solving are connected, for example, which values to consider before taking a certain action, and what knowledge to gather before making a
This fall, the UW-Madison College of Engineering will offer for the first time a course entirely based on digital learning simulations. First-year students will participate in two virtual internships—including Nephrotex—and propose solutions to realistic engineering design problems. New research suggests that participating in such simulations increases women’s interest in engineering and desire to pursue an engineering degree. The virtual internships were developed by WCER’s Epistemic Games Group in collaboration with faculty and students from the College of Engineering.

The Epistemic Games Group has received over $10.5 million in extramural grants to develop and study virtual internships and novel learning assessment tools, including a $3.5 million grant from the National Science Foundation, the largest grant the agency has ever awarded for research on games-based learning.

Anita Wager

David Shaffer

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use money when shopping with their families. She found that students who shopped with their families were able to quickly solve problems regarding currency and used powerful strategies.

Wager says this was the most authentic integration of out-of-school practice. It builds on informal strategies students use, and it explicitly addresses equity issues about the importance of connecting to practice.

Teacher-initiated situated settings

Some teachers developed rich lesson units that drew from an experience common to all students. Teachers first identified the mathematics content embedded in the shared activity and then linked it to school mathematics. Wager says this teaching practice can vary greatly in terms of complexity and time required to develop activities. A basic approach would be to take ideas from a shared reading to create word problems. As a more complex example, one fifth-grade teacher designed a unit she called the “International Bazaar.” Students explored several world currencies. They then worked in groups to manage “stores.” Each group had an imaginary currency and exchange rates that fluctuated daily. The activities of shopping and store management over a 3-week period covered geometry, fractions, decimals, percentage, and ratio.

Conclusion

During this research, Wager realized that teachers need significant support to be able to identify and build on students’ embedded mathematics practices. As noted in the examples above, the teachers generally made an effort to build on the informal strategies students use, but did not always do so in an effective way. With help, however, teachers can transform an activity that students find artificial into one that uses the students’ own informal math strategies to create richer, more meaningful experiences with mathematics. Wager has extended this work to her current project in which she and colleagues are facilitating professional development with preK teachers.

More about Wager’s work:
http://ci.education.wisc.edu/ci/people/faculty/anita-wager

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http://ci.education.wisc.edu/ci/people/faculty/anita-wager


More about Nephrotex: http://edgaps.org/gaps/projects/nephrotex/

particular kind of decision. ENA measures not only learning outcomes but also the learning process, and indicates the extent to which students are learning to think like professionals.

According to Shaffer, research findings reveal that women who participate in Nephrotex show an increase in motivation to persist toward an engineering degree. After playing the game, one student said, “Starting the class I wasn’t sure if engineering was right for me anymore, but finishing this internship I believe I could do well in a career in engineering and enjoy it.”

More about Wager’s work:
http://ci.education.wisc.edu/ci/people/faculty/anita-wager

More about Nephrotex: http://edgaps.org/gaps/projects/nephrotex/


Behavioral Support Should Be Culturally Responsive

A practice called Positive Behavioral Interventions and Supports (PBIS) aims to help students—and schools—by offering a supportive and predictable schoolwide social and academic environment. PBIS emphasizes the social and academic benefits of creating common, shared understanding of desirable behaviors among members of school communities.

In PBIS schools, teachers and students discuss and agree on desired behaviors and corresponding incentives and reinforcements for demonstrating these behaviors. In turn, families, teachers, and local leaders develop action plans for implementing a systemwide PBIS.

Aydin Bal, a professor in Rehabilitation Psychology and Special Education at UW–Madison, says PBIS is one of the most important innovations in special education to address discipline issues. He notes, however, that much of the original development of PBIS was done in suburban schools where assumptions about appropriate disciplinary methods are tied to the dominant, White culture.

Racial minority students bring to school valuable life experiences and cultural and linguistic practices. Yet, these practices are often devalued, and these students’ ways of knowing, behaving, and being are considered deficiencies. Too often, the preconception in schools is that these minority students are disruptive, resistant, and unlikely to succeed. This can lead to a great disparity in who is punished for certain behaviors, held back a grade, or even assigned to special education classes.

Multi-tiered system of supports

The effectiveness of PBIS is grounded in prevention. A multi-tiered framework shapes the delivery of services and supports. The first tier addresses the needs of all students. Educators teach social skills and expected school behaviors, create opportunities for students to practice those behaviors, and reinforce compliance. This tier emphasizes monitoring potential risk factors, such as low achievement, truancy, high student mobility, and histories of suspensions or expulsions.

The second tier addresses students who do not respond to the universal supports provided in the first tier. Teachers apply behavioral analysis and empirically supported behavioral interventions in smaller groups.

The cultural practices of schools are often entrenched institutional processes generating long-lasting effects, both positive and negative. They may reinforce structural systems of oppression in local neighborhoods and the larger society. For example, schools often keep children back a grade as a way to help struggling students, despite overwhelming evidence this practice is disproportionately used with racial minority students and that it produces damaging outcomes.

The third tier addresses students who don’t respond to the first two tiers. It provides highly specialized interventions from teams of special educators, behavioral interventionists, school psychologists, and counselors.

PBIS teams determine which students require more intensive behavior interventions and supports by monitoring a number of data sources and outcomes, such as office discipline referrals in a given time period and location, student attendance, tardiness, suspension,
and academic outcomes. These measurements focus PBIS on the social organization of the entire school as well as on individual student behavior.

Research has shown that racial minority students, especially African Americans, tend to be disproportionately punished more severely for less serious, more subjective reasons. Bal stresses, therefore, that PBIS must be sensitive to different cultural practices.

**Culturally responsive PBIS (CRPBIS)**

Cultural assumptions in the U.S. education system—reproduced year after year, decade after decade—shape the climate, rituals, and routines of every school. CRPBIS helps teachers and other stakeholders develop a critical awareness of how they think about—and assess—student behavior and interaction.

The following shifts in cultural practice are vital components of CRPBIS.

**From teaching desired behaviors to creating opportunities to learn.** CRPBIS encourages educators to create student-centered learning environments. Teachers give students opportunities to assess interactions with each other. Educators determine areas of strength and need. They create solutions that make sense in the context of that particular setting.

**From understanding culture as a variable to exploring school cultures as contextual mediators.** Educators, students, and families come together to discuss cultural patterns in the school and how they relate to student discipline and behavior. Stakeholders examine authentic student-student and educator-student interactions that are deemed desirable or undesirable. They explore how individual and group cultural experiences shape these perspectives.

**From local fairness to local to global justice.** CRPBIS is grounded in “local to global justice.” This perspective endorses more progressive and participatory forms of democratic politics and social activism. It encourages new ideas about regional confederations of grassroots and justice-oriented social movements. Stakeholders discuss equitable social interactions and outcomes across the classroom, school, community, and beyond. They work to improve these relations and their consequences within and outside school walls.

**From cultural assimilation to student, family, and community empowerment.** CRPBIS celebrates the power of the student, family, and community to determine what kinds of social interaction are desired in education settings. This perspective represents a shift away from the assumption that educators know best about behavior that is in the best interest of student learning and interaction. Preferences for student behavior should not be shaped solely by the educators’ cultural beliefs, values, and practice, nor the status quo for what is expected in schools.

CRPBIS involves students, families, and community members in identifying

1. Interaction patterns necessary for student engagement and learning,
2. Which interaction patterns are problematic, &
3. How students and families can participate in teaching and modeling desired behaviors.

Changing the culture of a school requires teachers, families, and students to commit to a continuous cycle of reflection and action in an open dialogue, not a top-down prescription of interventions. The goal is to eliminate oppressive and marginalizing institutional practices and jointly develop and implement contextually valid solutions from the ground up.

For more about Aydin Bal’s research see: http://www.crpbis.org/