EDUCATIONAL RESEARCH ABSTRACTS

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Editors' Note: As noted in previous issues of the *Journal of Mathematics and Science: Collaborative Explorations*, the purpose of this Educational Research Abstract section is to present current research on issues relevant to math and science teaching at both the K-12 and college levels. Because educational research studies are published in so many different academic journals and presented at so many different professional conferences, it is a rare public school teacher or college professor who is familiar with the range of recent reports on a particular instructional technique or curricular advancement. Indeed, the uniqueness of various pedagogical strategies has been tacitly acknowledged by the creation of individual journals and professional organizations dedicated to teaching in a specific discipline. Yet, many of the insights gained in teaching certain physics concepts, biological principles, or computer science algorithms can have generalizability and value for those teaching in other fields or with different types of students.

In this review, the focus is on "cutting edge" research. Abstracts are presented according to a question examined at a recent national educational research conference. Hopefully, such a format will trigger your interest in how you might incorporate new educational findings in your own teaching situation. The abstracts presented here are not intended to be exhaustive, but rather a representative sampling of recent research investigations. Please feel free to suggest future teaching or learning themes to be examined. Please send your comments and ideas via e-mail to gmbass@wm.edu or by regular mail to The College of William and Mary, P. O. Box 8795, Williamsburg, VA 23185-8795.

Cutting Edge Educational Research

"On the cutting edge!" What associations does that phrase generate? Current? Forefront? Fashionable? "Research on the cutting edge." What does that phrase produce? Cancer cures? DNA mapping? Nano-chips for 21st century technology? "Educational research on the cutting edge." Now what does that phrase engender? A comparison to military intelligence? Business ethics? Administrative wisdom? Is educational research an oxymoron with all the contradictions and irony of a "plastic glass," an "original copy," or a "divorce court?" Or could cutting edge educational research be a sharp slice into the Gordian knot of educational complexities and unknown solutions?

At the April 2001 Annual Meeting of the American Educational Research Association, thousands of educational researchers met in Seattle for a week of "cutting edge" research reports

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and discussion. As at any large educational conference, the topics covered were eclectic, the quality of those presentations varied, and the practical worth was very often idiosyncratic. So will cutting edge educational research lead you to more enlightenment or to more skepticism, or maybe just to new potential funding opportunities?

Some reformers have suggested the phrase "Technology on the bleeding edge." It is good to be on the "cutting edge," but much more dangerous to be on the "bleeding edge." Be a leader; be out front, but not too far ahead of the pack or you will leave them behind and perhaps get lost yourself. Even worse, the earliest pioneers always leave their backs unprotected and vulnerable to the arrows of outrageous fortune fired by critics and detractors or by collaborators trying to figure out what exactly to do. And arrows in the back leave a bloody trail only vultures are eager to follow.

Cut? Bleed? Penetrating thrusts into the realm of truth. Dull drubbings at the same old saws? Insightful conclusions that give us a new edge to persistent challenges? Misguided speculations that go over the edge? You be the judge. The following is a non-random selection of some papers presented at the premier educational research conference that relate to math and science education. Since these papers are indeed on the cutting edge, future revisions and additions are likely. A contact e-mail address or personal website URL is provided if you want to follow up on these cutting edge investigations.

- **What do school districts want math teachers to teach and what do the teachers actually do?**

What teachers are expected to teach and what they actually teach are not always the same thing. In fact, the tension between professional teachers making informed teaching decisions versus slavishly following a district curriculum guide or state curriculum standards has become much greater during this era of state-mandated, high stakes student assessments. The Ohio Mathematics and Science Coalition was especially interested in revitalizing and improving Ohio's mathematics and science education from preschool to university. They believed that four key questions must be answered before progress toward a world-class mathematics and science education system in Ohio could be accomplished: (1) What should students learn? (2) Who delivers the instruction? (3) How is instruction organized? (4) What have students learned?

In 1999, the North Central Regional Educational Laboratory (NCREL) conducted a survey of 280 high schools, middle schools, and primary schools in Ohio. The sample of schools was stratified by geography and school size. A school-wide survey was sent to each school's principal and samples of individual teachers at each school were also sent surveys. A total of 99 school surveys were received which resulted in a return rate of 35%. A total of 506 teachers returned the survey which resulted in the following grade level return rates: grades 3 & 4 - 59%; grades 7 & 8 - 62%; grades 12 - 51%.

Substantive findings:

Often the same mathematics topics are in the curriculum for many different grades. For example, seven mathematical topics (e.g., common fractions, estimating quantity and size) are listed for over ten consecutive grades.

Ohio's school district mathematics curricula repeats many math topics grade after grade. The average intended grade level for 24 of the 40 Third International Mathematics & Science Study (TIMSS) math topics falls in grade seven or eight in Ohio's math curricula.

Elementary and middle school teachers teach fewer math topics than their curricula demands.

Differences between Ohio and U.S. teacher patterns are minimal while Ohio teachers report covering many more math topics than their equivalent grade level teacher in Japan.

Most Ohio teachers rely on textbooks in more than half of their weekly math instruction. However, the variety of math textbooks used raises the question whether empirical research might identify which commercial textbook series most supports optimal student learning.

Teacher-led instruction was dominant at all levels—primary, middle school, and high school. However, whole class, small group, and individual work done under independent conditions were used to some degree by almost all reporting teachers.

> Practicing computational skills and explaining the reasoning behind mathematical ideas dominate how students spend their math instructional time at all grade levels.

The authors conclude that these data from Ohio are likely typical of the state of mathematics instruction throughout the United States. Fundamentally, they believe these data reinforce a most common sense conclusion: school districts and individual school teachers must think carefully about *what* math is to be taught, *when*, *to whom*, and *how*.

To accomplish such a challenge, teachers need assessment tools that tell them whether this week's instructional lessons were more or less effective than last week's. A reliance on once a year standardized exams will not provide such feedback when teachers most need it. Teachers also need access to instructional tools and encouragement to use them in creative ways. As the authors point out, teachers' classroom approaches are "enmeshed in a web of local practice and belief and history and constraints." Only when schools support teachers' instructional initiatives and provide resources that let those teachers be reflective about what really works with their students will world-class mathematics learning be accomplished.

Investigating Schools' Mathematics Curricula and Teachers' Instructional Practices Statewide: An Application of TIMSS-derived Tools in Ohio.
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- **What is the difference between an "idea-based" and a "case-based" approach in teaching adaptation and evolution in a high school zoology class?**

Teachers certainly want to provide their students with learning experiences that enrich and change their lives; or, at least, provide experiences that allow students to perceive and interpret the world in new ways. John Dewey wrote about such an experience that leads an individual to act with a fresh outlook, to change one's world view, and to reprioritize one's values. Kevin Pugh has applied this idea of a "transformative experience" to the realm of science education. What might happen if students were introduced to powerful scientific ideas that could inspire action and emotion?

Students in two high school zoology classes participated in the study. One group of eighteen students was randomly chosen to experience a two and a half week unit using an idea-based, transformative experience intervention while the other group of 22 students received a case-based learning activity. The idea-based approach used adaptation as a way to think about and appreciate how animals act. The case-based approach involved an inquiry lesson focused on endangered species. The idea-based class took an artistic crafting of content to change students' perceptions, meanings, and values (i.e., how to experience science ideas) while the case-based approach used class inquiry to help students understand the biological concepts of adaptation and evolution (i.e., how to do science.) Toward the end of the intervention, both classes took a field trip to a zoo, a context where the concepts of adaptation and evolution could be applied.

Pugh used an initial survey with both classes to identify their interests in the zoology course content, learning about animals, and the concepts of adaptation and evolution. This pre-test also measured their current conceptual knowledge and use of adaptation, evolution, and zoology content. The two classes were comparable on this initial assessment. After the first week of the intervention, Pugh found that 71% of the students who experienced the idea-based approach reported thinking or talking about examples of adaptations while only 17% of students in the case-based class reported thinking about adaptation. While students in the idea-based class reported more thinking about adaptation and evolution while visiting the zoo, the differences did not reach statistical significance compared to the case-based students. However, there were statistically significant differences in the frequency that idea-based students reported talking about these biological concepts in everyday life compared to the case-based students. There were no differences in the interests or values each group of students expressed toward animals or the ideas of adaptation and evolution.

One of the most surprising results Pugh found was that the students in the idea-based class performed significantly better on two essay questions about adaptation and evolution than the students in the case-based class. Conceptual understanding was not expected to be affected to the same degree as perception, interest, and value. Pugh does acknowledge there was substantial individual differences within each class on the variables assessed and that the concept of adaptation was more actively used, valued, and understood by all students than the concept of evolution. Nevertheless, he concludes that his research does indeed support the possibility that idea-based, transformative science experiences can lead to enduring changes in how students see, understand, value, and act in the world outside the classroom.

Using Concepts to Foster Enriched Experiences in Students' Everyday Lives
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- **How well do college students use the Internet to find scientific information?**

Trumpeting the unparalleled access to information through the Internet has almost become a 21st century cliché. Even the phrase "information highway" has been so overused that it is hard not to have heard the strained analogies pundits have created: "Don't be roadkill on the information superhighway!" "Where is the off-ramp on the information superhighway?" "I want less congestion and more speed on my information superhighway." "Lots of highway and no good places to go." "Who gets to put up toll booths on the information superhighway and what will access cost me?" and "I invented the information superhighway." Past research has identified four factors that contribute to an individual's success in finding information in an electronic environment: domain knowledge, search expertise, situational interest, and individual interest.

MaKinster, Beghetto, and Plucker presented in-depth case studies of college students' use of the Internet to discover scientific information. Seven students with differing self-reported Internet use (one to five hours average per week) were given the task to gather information from the Internet to be used in constructing a web page on Newton's Third Law (i.e., whenever one body exerts a force on a second body, the second body exerts an equal and opposite force on the first.) Students were given twenty minutes to search the Internet for this information and paste it into an HTML document while a videotape and computer activity-tracking program recorded their actions. At the end of the twenty minutes, students were shown the videotaped session and asked to explain what they were doing at each point in their search. An audiotape was made of their "think aloud" answers. The researchers analyzed all the available information to differentiate among the three categories of Internet searchers that emerged -- successful (two students), moderately successful (two students), and unsuccessful (three students.)

The researchers concluded that three factors impacted successful searching: understanding how scientific content is organized; evaluating the descriptors and contents of a web page, and using keywords in search engines. Two students were successful in finding the most relevant information in the fastest time. With respect to "domain knowledge," they showed a use of very specific search terms, probed for deeper levels of information, displayed a deliberate search strategy, and recognized the way information was organized in web pages. With respect to "search expertise," they used sophisticated search strings in their search engine of choice and also showed a purposeful strategy in judging the results. Finally, the successful searchers showed low distractibility with the extraneous features and diversions so evident on the Internet. These successful students were very conscious of what they were looking for and how they could use that information to construct an effective web page on Newton's Third Law.

The implications of this study for educators who want their students to retrieve information via the Internet is clear. Even college students with reasonable familiarity to the Internet differ greatly in their abilities to find, judge, and use web-based scientific information. Teachers cannot assume all students are equally competent in their web search strategies or their critical thinking decisions in using whatever information they find. If teachers expect students to use the Internet as a science resource, they must provide more direct instruction and organizational assistance to develop the skills students will need to keep from crashing on the information superhighway.

Why Can't I Find Newton's Third Law?: Case Studies of Students Using the Web as a Science Resource

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- **What research tool can give an accurate report on teachers' instructional practices?**

One critical challenge in relating classroom teaching reform efforts with student achievement is having a valid way to document what instructional practices teachers are actually using. Without an accurate method to document teachers' teaching actions, there is no trustworthy way to identify what classroom practices actually improve students' learning. While many studies have asked teachers to describe their own teaching, doubts regarding the reliability and validity of these self-reports have been raised. Shim, Felner, Shim, and Noonan have directly addressed the psychometric attributes of one such self-report instrument, the High Performance Learning Community Assessment (abbreviated HiPlaces Assessment.)

The HiPlaces Assessment asks teachers to report on the frequency of their use of various instructional practices. Teachers use a 7-point scale ("Daily"; "Several times a week"; "Weekly"; Several times a month"; "Monthly"; "Several times a year"; "Never") to answer 56 items characterizing different possible classroom routines. Many of the 56 items originated from a 1976 instrument, the Classroom Instructional Practices Scales, with additional items added or modified by the authors during their survey work with middle school teachers in the early 1990s.

To verify the reliability and validity of the current instrument, Shim, *et al.* used factor analyses, internal consistency calculations, and correlations between teacher and student reports of instructional practices. Between 1992 and 1997, over 25,000 sixth to eighth grade teachers in sixteen states completed the HiPlaces Assessment.

Factor analysis on the annual survey data supported an eight-factor solution (confirmatory factor analyses during the five years ranged from .83 to .86.) These eight factors were given sub-scale labels that best captured the constructs being assessed: "Small group active instruction"; "Community-based learning opportunities"; "Citizenship and social competence instruction"; "Integration and coverage of health topics"; "Integration and interdisciplinary practices"; "Critical thinking enhancement practices"; "Mastery-based assessment and student recognition"; and, "Practices for heterogeneous groups." Some items which loaded on multiple factors were identified to be modified on future versions of the instrument which should lead to even stronger sub-scale factors.

Using coefficient alpha statistics on the HiPlaces Assessment data each of the five years, Shim, *et al.* found that six sub-scales had Cronbach Alpha values that varied between .77 and .91. Two scales ("Mastery-based assessment and student recognition" and "Integration and coverage of health topics") showed less internal consistency with alpha coefficients in the range .76-.78 and .58-.62, respectively, during the five years. The overall reliability of the total scale was consistently high during the five years—.95 for the first four years and .96 for the fifth year.

During the 1992 to 1997 period in selected classrooms, student reports on the frequency of their teachers' instructional practices were also collected. Items from two sub-scales ("Small group active instruction" and "Integration and interdisciplinary practices") were given to both teachers and students. There were statistically significant correlations between teacher and student reports on the two sub-scale items—.52-.66 and .61-.76, respectively, across the five years.

Because the cost of repeated classroom observations to document teachers' instructional practices is so high, the use of self-report questionnaires is a much more cost-effective way to accomplish the same result. However, those questionnaires must provide reliable and valid descriptions of teaching practices or low cost will also equal low value. This extensive five-year analysis of the High Performance Learning Community Assessment suggests that survey data on instructional practices can provide reasonably accurate descriptions of teachers' frequency of use of those classroom practices recommended in numerous reform initiatives.

Multi-dimensional Assessment of Classroom Instructional Practice: A Validity Study of the Classroom Instructional Practice Scale.
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- **What should a classroom observer recognize and record in a science lesson?**

The teacher can teach good. If only the student would learn good! No matter how a teacher designs classroom lessons, it is how the student interprets and incorporates that experience that produces real learning. The Multiple Representation Model is a system-based procedure to examine science lessons by depicting the relationships of the teacher's external representations and the student's internal representations. It focuses on science lesson activities such as manipulating, pictorializing, symbolizing, and concrete modeling as they interact with the student's generalizing new ideas into "mental models" or "schemas."

Carol Stuessy has developed a Multiple Representation Model Observation Protocol (MRMOP) which prompts an observer to record the representations received and used by learners during a science lesson. Specifically, the observer records the number and durations of lesson segments, the types of representations (objects, symbolic, pictorial) received by learners, and the student-centeredness of each segment. Five categories are used to characterize student-centeredness: students listening; students responding orally or in writing; students doing the same task in pairs or small groups under teacher supervision; student groups working on different tasks under teacher supervision; students working together with little teacher supervision; and, students carrying out plans independently with minimal teacher input.

In her work with pre-service teachers, she has reported that the MRMOP serves as a useful reminder for organizing classroom learning experiences. It helps pre-service teachers think about how to translate concrete classroom experiences into symbolic and pictorial representations. In order to help novice teachers think even further about the ways students receive and respond to lesson segments, Stuessy has added a six-point complexity scale from Replication (students listen, observe, measure, recall, show) through Rearrange/Transform (students organize, compare, classify) to Generate/Create (students analyze, summarize, design, model, evaluate).

Stuessy proposes future uses of the MRMOP in developing "lesson profiles" of exemplary science teachers to identify the best balance of lesson segments, lesson complexity, and their effects on student receiving and responding. She is also in the early stages of designing a computer-based system to facilitate the data entry, storage, manipulation, and visualization of MRMOP observation results. Such formal measures of lesson structure should prove valuable for mentoring novice teachers and for evaluating the impact of initial training and professional development programs.

A Systems Approach to Classroom Observation of Multiple Representations in Teaching and Learning in Mathematics and Science
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- **What would reformed teaching look like and how can I document that?**

"Reform teaching? I really can't define it, but I know it when I see it!" Maybe, but it is a supreme court fast break from an intuitive understanding of a concept to one that can be operationalized and tested in real classrooms. As part of the Arizona Collaborative for Excellence in the Preparation of Teachers, Michael Piburn and Daiyo Sawada have created an instrument to do just that.

The Reformed Teaching Observation Protocol (RTOP) draws on constructivist learning theory and national math and science education standards to identify prototype classroom features recommended for reformed teaching. RTOP consists of 25 items divided into three sections: lesson design and implementation (5 items); content—propositional and procedural knowledge (10 items); and classroom culture—communicative interactions and student/teacher relationships (10 items). Observers use a five-point scale ("Never occurred" to "Very descriptive") to characterize what they see in the math or science classroom. Sample items related to lesson design include: "The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent in them" and "In this lesson, student exploration proceeded formal presentation." Sample items for content include: "The lesson promoted strongly coherent conceptual understanding" and "Students made predictions, estimations and/or hypotheses and devised means for testing them." Sample items for classroom culture include: "There was a high proportion of student talk and a significant amount of it occurred between and among students" and "Active participation of students was encouraged and valued."

Psychometric characteristics of the RTOP were also calculated during the Fall 1999 Semester. Two trained observers simultaneously made sixteen independent observations in Arizona Collaborative reformed math and physics courses using the RTOP. The inter-rater correlation for these sixteen paired observations was $R^2 = 0.954$. Two other observers visited eight biology classes and the correlation of their RTOP ratings was $R^2 = 0.803$. Construct validity was supported by using individual subscales as predictors of the RTOP total score. An exploratory factor analysis of 153 classroom observations from 62 university courses, 26 community college courses, 37 high schools, and 28 middle schools revealed three factors—"inquiry orientation," "content propositional knowledge," and "collaboration."

Predictive validity was supported through an analysis of six university-level courses involving six mathematics instructors, six physical science instructors, and four physics instructors who gave students content pre-tests and post-tests. Each instructor was also observed a minimum of two times during the semester using the RTOP. The correlation between the RTOP mean observation score and normalized student gain scores for these six math and science courses was 0.88 which was statistically significant at the .01 level.

Piburn and Sawada are continuing to examine the factor structure of the 25 items to discover the interrelationships among sets of items. As is typical of most social science instruments, the items constructed for each subscale do not always match the subscales reflected in the factor analysis. While some future item revisions may make the RTOP even more "factorially distinct," the RTOP now offers an acceptably reliable and valid instrument to operationalize reformed teaching. If you want to document whether a math or science classroom fits the reformed teaching model, using the RTOP is a legitimate strategy to employ. In fact, the RTOP items could also be given to beginning and experienced K-16 teachers as a self-rating exercise to operationalize what reformed teaching could mean in their own math and science instruction.

Developing and Utilizing an Observation Instrument to Define, Quantify, Assess, and Refine Reformed Teaching Practice in K-20 Science and Mathematics—The Reformed Teaching Observation Protocol (RTOP)
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The Arizona Collaborative for Excellence in the Preparation of Teachers also sponsored a symposium at AERA where the impact of reformed teaching and the use of the RTOP was examined in various contexts. If any of the following questions intrigue you, contact the authors to get more details.

What difference does reformed teaching make:

...to pre-service education students?
Teacher Education for Arizona Mathematics and Science TEAMS 1996-2000:A Summative Evaluation
Michael Piburn and Dale Baker, Arizona State University

...to pre-service biology teachers?
Developmental Level and Overcoming Nature of Science Misconceptions Among Pre-Service Biology Teachers
Anton Lawson, Arizona State University

...to prospective elementary teachers?

An Evaluation of Reforms Instituted in Mathematics Courses for Prospective Elementary Teachers

Irene Bloom, Arizona State University

...to secondary science teachers?

Using the Reformed Teacher Observation Protocol (RTOP) as a Catalyst for Self-Reflective Change in Secondary Science Teaching

Dan MacIsaac, Northern Arizona University; Kathleen Falconer, Arizona State University; and, Daiyo Sawada, University of Alberta

...to college students in a large enrollment physical science course?

Effect of Reformed Courses in Physics and Physical Science on Student Conceptual Understanding

Kathleen Falconer, Arizona State University; Joshua Mangala, Mesa Community College; Susan Wyckoff, Arizona State University; and, Daiyo Sawada, University of Alberta

..in guiding student teachers?

Using the RTOP for Feedback to Student Teachers: A Metamorphosis of Method

Jeff Turley, Michael Piburn, and Daiyo Sawada, Arizona State University

...to beginning teachers during their first three years?

Tracking Transfer of Reform

Eugene Judson, Arizona State University and Daiyo Sawada, University of Alberta

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- **To what degree do inquiry-based teacher practices actually influence science achievement?**

Certainly inquiry-oriented instructional practices have been widely touted as The Way to enhance students' science interest and understanding. The National Science Education Standards were developed to increase science achievement for all students. However, the student background variables of SES, race, and gender that have traditionally influenced academic achievement have not been examined within the context of these inquiry-based instructional reforms. Clare Von Secker has undertaken such an examination.

The data for this investigation were the tenth grade follow-up survey of the National Educational Longitudinal Study sponsored by the National Center for Education Statistics. This follow-up study in 1990 comprised a national probability sample of public and private 1989-1990 tenth grade students. Von Secker used a sample of 4,377 students who had demographic data, tenth grade science achievement data, and their biology teachers' questionnaire data. Gender, socioeconomic status quartiles (based on parent questionnaire income, occupation, and education information), and minority race-ethnicity (African-American, Hispanic and American Indian) were the demographic variables used to classify the students. Five teacher practices reported on the questionnaire were used to classify their degree of inquiry-based teaching: a) student interest and engagement; b) using appropriate laboratory techniques; c) problem-solving; d) conducting further study; and, e) scientific writing. Her analysis used two-level hierarchical linear models to identify the associations of teacher practices with student achievement and student demographic variables.

A significant amount of variability in tenth grade science achievement was accountable for by gender (.48 SD lower for females), minority status (.51 SD lower), and socioeconomic status (.3 SD for every quartile increase in SES). The five identified teacher practices were associated with higher science achievement for all students with achievement increasing by .58 SD for every 1 SD increase in the emphasis teachers placed on an inquiry approach using the five practices. (Increases in student achievement for each specific practice were .22 SD, .28 SD, .33 SD, .36 SD, and .22 SD, respectively.) The real surprise was in the effects of specific teacher practices on the three-way interaction of SES, minority status, and gender. For example, in classes where the teacher emphasized student interest, majority female achievement rose almost three times more than for minority females. The effects of this teacher practice was negligible for majority males, but emphasizing interest in science was associated with less equitable achievement for minority males, especially those from low SES families.

The degree of teacher emphasis on the four other inquiry-based teaching practices also resulted in complicated interactions with gender, minority status, and SES. Each teacher practice was associated with a differential science achievement impact depending on the demographic student characteristics. In Von Secher's own words, "the impact of inquiry-based teaching is sensitive to social context differences and these practices are as likely to exacerbate achievement gaps among some groups of students as they are to narrow them among others." Her analysis reveals once again that no instructional practices, traditional or reform, are a panacea for low academic achievement, especially among disadvantaged students. Teachers must pay careful attention to the individual differences among students and how their various instructional practices affect those students.

Effects of Inquiry-Based Teacher Practices on Science Excellence and Equity
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Next Steps?

Hopefully, this rough cut of recent educational research has you cutting your teeth on new teaching and learning possibilities. Remember cutting edge research can cut both ways and not all of it will cut the mustard in your own classroom. So now it is time for you to cut loose, cut to the chase, and cut a deal. How can you use any of these research findings to cut a new path in your own teaching? And that's my last cutting remark! ■