What's the Difference?
Teaching Mathematics to Standards in a Distance Learning Environment.

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Abstract: In the years since the NCTM Curriculum and Evaluation Standards were first published in 1989 and the NCTM Professional Standards in 1991, and with the recent publication of the new NCTM Principles and Standards for School Mathematics, 2000, many K-12 teachers of mathematics have made great strides towards realigning their mathematics curriculum and teaching methods and strategies so as to conform more closely to the recommendations of these documents. Reform in mathematics teaching is widespread, even if spotty, and many teachers have been encouraged to try new strategies such as group and cooperative learning, integration of technology in the classroom, and new, engaging curriculum that requires conceptual understanding by the students, rather than only procedural knowledge.

With the advent of distance learning technology, and its anticipated widespread use in mathematics instruction, particularly in rural environments where many of the children may also be at-risk and/or high-need/low-achieving children, what will be its effect on continued movement towards reformed and revised teaching and learning? For example, how will teachers be able to conduct group and cooperative learning activities in such an environment? How will they be able to promote the use of technology such as graphing calculators and computers to facilitate mathematics learning in such an environment? This paper will begin to address these issues and will look at research questions directed at how teachers might continue to align their teaching with current standards in such an environment.

Research Focused on Teaching & Learning (Distance-Delivered Mathematics)

Considerable research has been devoted to teaching and learning mathematics at the middle-school through higher-education levels that are targeted by the Center for Learning & Teaching in the West (CLTW) Teaching & Learning research team. However, little research has been reported on the interaction of teaching, learning, and distance education in mathematics. *Specifically, how can we teach mathematics effectively in an on-line environment and what constitutes productive learning within such an environment?*

Members of the CLTW Teaching & Learning research team, working collaboratively with the Distance Education research group, will investigate this question. The *NCTM Principles and Standards for School Mathematics* (referred to as *2000 Principles & Standards*) endorse the use of technology in learning mathematics, but the document does not specifically address particular issues in using such a delivery method.

The *2000 Principles & Standards* offer a context for mathematics educators to consider when teaching. Will these principles equally apply in the distance education setting?

The *2000 Principles & Standards* lists six principles that form the keystone of any mathematics curriculum. They are: The *Equity* Principle, the *Curriculum* Principle, the *Teaching* Principle, the *Learning* Principle, the *Assessment* Principle and the *Technology* Principle. I would like to look at each of these through the lens of distance delivery.

The *Equity* Principle states that "Excellence in mathematics education requires equity – high expectations and strong support for all students." Is it possible to provide excellent mathematics education via distance learning? Given the current inequitable distribution of computer technology, and the inequitable access to such technology, the answer is not clear. What is it that we as educators must do to ensure a level playing field in access to on-line mathematics? Is the offering of distance classes a form of tracking? We must not espouse a "trickle down" approach to mathematics education in any form.

The *Curriculum* Principle states that "A curriculum is more than a collection of activities: it must be coherent, focused on important mathematics, and well articulated across the grades". It is all too easy for curriculum to be fragmented, incoherent, scattered, and shallow. What additional constraints does distance learning impose on curriculum? Will it be possible to adhere to a curriculum while teaching in this fashion?

The *Teaching* Principle states that "Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well." What are the additional challenges to educators in providing effective mathematics teaching via distance learning? Are there additional challenges to knowing what students need to learn, and are learning in this environment? What additional obstacles are there to authentic assessment?

The *Learning* Principle states that "Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge." Is it possible for students to learn with understanding in this environment, and how will we as educators know? Will we know whether they are actively learning?

The *Assessment* Principle state that "Assessment should support the learning of important mathematics and furnish useful information to both teachers and students." What, if any, additional constraints are put on assessment in such an environment? What issues must we be aware of in trying to develop valid assessment tools?

The *Technology* Principle states that "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning." On the one hand, this may seem to be a moot point. After all, students are using computers to access the course. But, is this what is meant by this principle? What will be the challenges to guiding students in the use of graphing calculator technology, computer algebra systems and mathematical software programs, all in a distance environment?

An examination of these Principles through the lens of distance education raises more questions than it answers. But if we are to provide equitable mathematics education, viable teaching and learning, and accurate assessment, then we must address these questions.

Further Challenges

In a response to an editorial by David Moursund (2000), entitled *A Typical Student in 2016*, Tara Beau and colleagues express concern for the limited face-to-face social interactivity inherent in distance learning. "We wondered if this would create a wider gap between the haves and the have-nots where the most motivated students would no longer attend a traditional school." (Beau et al., 2000) Clearly, this poses a challenge for developers of on-line courses.

Odasz (1999) outlines some differences experienced in teaching on-line classes. On-line relationships among students, and also between students and teacher, can be very different than face-to-face relationships. They can be more intimate and articulate because messages can be authored without time pressures. Written interaction is more mind-to-mind than face-to-face interaction, allowing for more thoughtful, considered, and measured discussion and responses.

The classroom often does not allow private communication between teacher and student, whereas many teachers have been pleasantly surprised by the deep relationships they have developed with many students through on-line interaction. This has been particularly effective with at-risk students (Odasz, 1999), and may generalize to the types of students that are the focus of CLTW. For example, Odasz documents, at-risk students with a history of disinterest in reading and writing will teach themselves keyboarding and spelling when given the opportunity to interact with on-line peers.

In a seminal study on internet use, Hoffman and Novak (1998) systematically investigated the difference between U.S. whites and African Americans regarding computer access. Whites are currently more likely to have computer access, are more likely to have used the web (26% vs. 22%), and are more likely to have used a computer at home (14.7% vs. 9%). African-Americans are more likely to have used a computer at school. Whites are more likely than African Americans to own a home computer.

Level of education does not account for racial differences in home-computer ownership, while level of income does not explain racial differences in access to work computers. After accounting for education, whites are more likely than African Americans to own a home computer, while, after adjusting for income, African Americans are more likely than whites to access a computer at work. (These data cannot be used to evaluate differences in school technology.)

Policy implications, Hoffman and Novak conclude, are obvious: "to ensure the participation of all Americans in the information revolution, it is critical to improve the educational opportunities for African Americans." The same can be said for Native Americans. CLTW research will investigate ways in which this can be implemented.

Sakshaug (2000) provides an overview and history of the uses of distance education in general, and, more particularly, in mathematics instruction. She provides several sources of information for designers of distance-education courses, and discusses the direction that distance education should take. Salomon (1998) points out that technology could further advance the cause of educational reform by creating new learning environments that would enable the learner to become engaged. The hallmarks of these are: (a) teamwork that allows social facilitation and scaffolding of an individual's learning as well as the emergence of distributed knowledge; (b) authentic interdisciplinary problems that encourage cognitive networking; (c) the diverse and intensive employment of technology to serve as tools for information gathering, selection, communication, and construction; and (d) guidance by teams of teachers to allow for the necessary rich improvisation. (p. 7)

Sakshaug points out that "mathematics educators need to establish relationships between learners and themselves and among learners in distance education settings. They need to create interactive environments in which the learner is engaged and feels a part of the learning experience. They also need to have training in the use of distance technology and how it is most effectively used." (p. 122) She also notes that research in distance education involving mathematics is virtually non-existent. "Educational institutions that offer mathematics courses via distance education need to be gathering evidence about how well their programs are meeting the needs of learners both cognitively and affectively. They need to provide support for mathematics teachers in the implementation of distance education, and in the implementation of the use of technology in general." It is clear that the need for research is there, and CLTW will help to address that need.

Several issues highlighted above are of special relevance to CLTW research:

Engagement in Learning Beau and Odasz note the lack of in-person social interaction in distance education, and wonder if this will seriously reduce student engagement or, alternatively, present opportunities for more intimate and reflective teacher-student and student-student interactions. And while Beau cautions that highly motivated, self-directed learners may opt for the autonomy provided by distance education, leaving the regular classroom to less-committed students, Odasz notes that at-risk students may be particularly attracted to distance learning because it allows more frequent, meaningful interactions with the instructor and peers. Poor student engagement and attendance, low rates of advanced course-taking, and high dropout rates are a serious concern in CLTW partner schools. Thus effective uses of distance technologies to stimulate student involvement in mathematics learning will be a research focus for CLTW, building on strategies proposed by Salomon and others. The Center will investigate distance-education strategies on a continuum, ranging from activities that supplement and extend in-person instruction, to those that supplant it.

In addition to exploring distance delivery as a way to engage middle and high school students, Center researchers will also investigate engagement strategies in post-secondary settings. For example, some community colleges and tribal colleges affiliated with CLTW provide mathematics instruction to students working toward a GED, and all provide additional preparation for students not yet ready to learn undergraduate mathematics. Some campuses are meeting this need, in part, via distance coursework, thus providing more flexible scheduling for students who are full-time workers and/or full-time parents. Collaborating with tribal and community college faculty, the CLTW will explore ways that research can contribute to the engagement and success in mathematics of students making the transition from high-school to community-college study.

Access to Learning Resources The majority of CLTW partner schools are rural; others are urban but have a history of inadequate access to educational resources; and almost all serve significant numbers of minority and low-income students. According to mathematics teachers at these schools, most students do not have access to a home computer, although computers and Internet access are fairly accessible in the schools themselves. What are the implications for CLTW research? First, building on the work of Hoffman and Novak (1998) and the just-released U.S. Department of Commerce report on internet use in America (2002), CLTW will determine the extent of computer and Internet access at home and school by Native American, Hispanic, and other student populations in partner schools. To what extent is access for these groups similar to the unacceptably low levels reported for African American students?

With accurate baseline information in hand, CLTW researchers will address the question posed by Roblyer and Erlbaum (1999) regarding how best to provide access to distance technologies and distance education to students with diverse backgrounds and limited learning opportunities. Responses to a Center needs survey indicated strong interest among mathematics teachers in learning how to use distance technologies in the classroom. As the Center works with partner schools to address this need, the professional-development interventions will be closely linked to a research agenda that examines how students' confidence and skill in accessing Internet-based resources for use in mathematics problem solving can be developed. Special attention will be paid to strategies that do not disadvantage the roughly two -thirds of underrepresented minority students aged 10-17, compared to one-third of white and Asian-American students, who do not have internet access in their homes (U.S. Department of Commerce, 2002).

A related concern is the effectiveness of distance-delivery mathematics courses currently available to students in Center schools, and how these might be improved. Rural western schools, including those in CLTW states, are already offering certain mathematics courses, ranging from algebra to more advanced courses, via satellite, interactive video, or asynchronously on the Internet. School administrators in CLTW partner schools observe that this practice is on the rise due to (a) the difficulty of hiring and retaining qualified mathematics teachers; and (b) the economics of providing advanced courses for scattered pockets of rural students. Empirical evidence is almost nonexistent on the effectiveness of distance mathematics offerings for middle and high school students; most published reports are either unadorned course descriptions, or, curiously, theory-free comparative studies of outcomes for distance learners compared to control-students. CLTW researchers plan to fill this gap.

Concept-Development in Mathematics Much of the existing literature on distance education focuses on issues of social interaction, engagement, and access. Only a handful of studies in any subject area explore the efficacy of various processes in promoting conceptual understandings in a distance environment. On many topics of importance in mathematics learning, there is no research at all. For example, despite a fairly substantial body of research demonstrating the feasibility of collaborative learning and community-building via asynchronous computer conferencing, a thorough review of the literature Myers (2002) identified no work on collaborative mathematical problem-solving that described and analyzed the content and nature of participants' interactions in any detail.

Within the context of high-need student populations that CLTW addresses, Center researchers will explore how concepts and problem-solving strategies, such as the visual representation of mathematical ideas, collaborative learning in mathematics, and communication of mathematical ideas and symbols—all challenging for students and their instructors within the traditional classroom—will be introduced effectively in an electronic learning environment. *In what ways can inherent strengths of distance environments (e.g. ready access to mathematics software and web-based resources; ease of teacher-student and student-student discourse; wait time for reflection and measured response; a written record that allows participants to retrace the progression of individual and group thinking; equitable participation by females and minority students, perhaps due to participant relative anonymity), be used to strengthen student understanding of specific mathematics concepts?* Salomon proposes reform-linked strategies appropriate for distance education—for example, teamwork and dialogue leading to growth in individual and group knowledge; varied and continuous employment of technology for information gathering, construction and communication; use of a wide range of electronic resources for interdisciplinary problem solving; and guidance by teams of instructors with different expertise. *If these and other interactive strategies are properly employed in a distance environment, will the end result be student development of solid conceptual understandings and problem-solving skills?*

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