

Double Visions: Educational Technology in Standards and Assessments for Science and Mathematics

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For educational technology integration in content disciplines to succeed, teachers and teacher educators need clear standards delineating why, how, where, and how much educational technology they should include in their teaching. This paper examines the visions offered by current science, mathematics, and educational technology standards for educational technology integration in K-12 schools. Since national assessments exert a profound influence on what teachers and students choose to teach and learn, the vision of educational technology use supported by national assessments is also examined. The National Council of Teachers of Mathematics Standards (NCTM, 2000. *Principles and Standards for School Mathematics*. Retrieved April 6, 2002 from <http://standards.nctm.org>), the *National Science Education Standards* (National Research Council (NRC) 1996. *National Science Education Standards*. Available at <http://books.nap.edu/catalog/4962.html>), and the *National Educational Technology Standards* (International Society for Technology in Education (ISTE) 2000. *National Educational Technology Standards for Students: Connecting Curriculum and Technology*, ISTE, Eugene, Oregon) provide different visions of educational technology use in the classroom. In addition, the current technology use policies for national assessments in science and mathematics, in particular the college admission tests (ACT, SAT I and SAT II subject area tests), Advanced Placement (AP) course assessments, and the Praxis Series assessments indicate that while mathematics assessments often recommend or require the use of educational technology, few science assessments permit the use of educational technology by students. Recommendations are offered for science educators regarding teacher preparation for the technology-rich classrooms of the future.

KEY WORDS: standards; national assessments; science; mathematics; educational technology.

INTRODUCTION

Interest in the use of educational technology has been powered at least in part by the widespread recognition of the transformative impact of electronic technologies on the American economy. In 1996, seeking to capitalize on the dramatic innovations in the early and mid-1990s, then U.S. Secretary of Education Richard Riley released *Getting America's*

Students Ready for the 21st Century: Meeting the Technology Literacy Challenge (USDOE, 1996), the nation's first educational technology plan. This document envisioned effective use of educational technology from elementary through secondary schools in order to better educate America's school children and prepare them for the workplace of the new century. In December 2000, Riley released a follow-up report, *e-Learning: Putting a World-Class Education at the Fingertips of All Children* (USDOE, 2000) in which he shared the astonishing progress the nation had achieved toward reaching the goals established in 1996 and identified five new national educational technology goals: (a) All students and teachers will have access to information technology in their classroom, schools, communities, and homes;

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(b) All teachers will use technology effectively to help students achieve high academic standards; (c) All students will have technology and information literacy skills; (d) Research and evaluations will improve the next generation of technology applications for teaching and learning; and (e) Digital content and networked applications will transform teaching and learning (USDOE, 2000).

Among other recommendations, the author highlighted the importance of preparing teachers for a style of teaching dramatically different from historical models. In specific, Riley called for Americans to

... Include technology and information literacy in state and local standards for what students should know and be able to do; ensure students use technology appropriately and responsibly; develop new student assessment tools; and strengthen partnerships with industry to help meet the workforce needs of the future (USDOE, 2000, p. 6).

For the purposes of this discussion, educational technology tools will be defined as computer- and calculator-based electronic devices used to complete an educational task. Examples of educational technology tools include digital microscopes, digital cameras, telecommunications tools such as E-mail or using Internet web sites, PowerPoint and other multimedia presentation software, electronic probe ware used with handheld calculators or computers, simulations either online or on CD-ROM, CD-ROM software applications, spreadsheets, electronic calculators, and web page authoring software.

How can the science education community respond to this challenge? In a white paper prepared for the U.S. Department of Education's Forum on Technology in K-12 Education (USDOE, 2000), Steven Rakow, past president of the National Science Teachers Association summarized the current and potential impact of educational technology on science teaching in K-12 schools. While recognizing the importance of both access and quality as key factors for technology integration in classrooms of the future, Rakow (1998) encouraged science educators to actively influence the conceptualization and development of new technologies for science teaching. Rakow encouraged science educators to strive to align new technologies with the *National Education Standards* (NRC, 1996) and work to make educational technology an integral part of the science curriculum.

For technology integration in content disciplines to succeed, teachers need a clear vision of how to

make educational technology a vital part of their curriculum. Educational standards should identify how educational technology may be used appropriately in teaching. In addition, national educational testing programs exert a strong influence on educators by operationally defining what is important for students to know and be able to do. Do current science, mathematics, and educational technology standards support a common vision for educational technology integration in K-12 schools? Do commonly used national assessments support the vision of technology use provided in the standards? In other words, are national standards and assessments providing a vision for teachers that will guide them to prepare their students for a technology-rich future?

METHODOLOGY

To determine the vision provided by national standards for the use of educational technology in science and mathematics teaching, the most recently published national standards in mathematics, science, and educational technology were closely read and analyzed for explicit references to the use of educational technology in classroom teaching. The documents examined include the *Standards 2000* document published by the National Council of Teachers of Mathematics (NCTM, 2000), the *National Science Education Standards* (NRC, 1996) published by the National Research Council and the *National Educational Technology Standards* produced by the International Society for Technology in Education (ISTE, 2000). Explicit references to educational technology inclusion were noted and analyzed for common themes in order to provide a description of the vision of instructional technology use provided by each document. Cross case analysis compared and contrasted the visions provided by the science, mathematics, and technology standards documents. In addition, broad policy statements and examples of educational technology use in sample lessons were noted.

Because of the role of national assessments in operationally defining what is important for students to know and be able to do, national assessments were analyzed to determine what vision they offer teachers regarding educational technology. The current technology use policies for national assessments in science and mathematics, in particular the college admission tests such as the Scholastic Aptitude Test 1 (SAT I), SAT II subject area tests, the American College Testing Assessment (ACT), Advanced Placement (AP)

course assessments, and the Praxis Series assessments (often used for teacher licensure) were examined.

A CLOSER LOOK AT THE MATHEMATICS, SCIENCE, AND EDUCATIONAL TECHNOLOGY STANDARDS

Educational Technology in the Mathematics Standards

In 1989, the National Council of the Teachers of Mathematics (NCTM, 1989) released *Curriculum and Evaluation Standards for School Mathematics*, designed to raise student expectations and performance. In 1991, NCTM followed up with *Professional Standards for School Mathematics* and in 1995 with *Assessment Standards for School Mathematics*. These pioneering efforts paralleled a grade level of improvement on test scores for students in grades 4, 8, and 12 on the National Assessment of Educational Progress (Lappan, 2000). To strengthen and gain broad support for their work, mathematics educators sought to build consensus within their professional membership through extensive evaluation, testing by practitioners in the field, reflection, and revision. In the spring of 1997, NCTM writing teams started work on the most recent iteration of the project, the *Standards 2000* document (NCTM, 2000).

Members of the Standards 2000 Writing Group and Standards 2000 Electronic Format Group represented many diverse educational interests with a wide variety of skills and expertise. Mathematicians, teachers, teacher educators, administrators, and researchers collected and distilled information and advice from more than 650 individuals and 70 groups, including school study groups, graduate seminar participants, and sessions held by NCTM affiliates. The writing team provided nearly 30,000 copies of the standards draft document to interested individuals, and many more viewed the work from the NCTM web site. The NCTM leadership instructed the Writing Group to create standards that would (a) improve on previous standards documents; (b) integrate the various classroom segments of the three earlier standards documents produced by NCTM (1989, 1991, 1995); and (c) provide standards for four grade levels: prekindergarten through grade 2, grades 3–5, grades 6–8, and grades 9–12.

The Electronic Format Group, a parallel group appointed by NCTM at the same time as the Writing Group, received the challenge to (a) identify

alternative methods to present and distribute the new standards document; (b) identify ways to integrate technology-based materials in the standards; (c) inform the Standards 2000 Writing Group about current uses of technology; and (d) provide appropriate examples of technology use for the Writing Group team (NCTM, 2000).

From the outset of the Standards 2000 project, the National Council of Teachers of Mathematics acknowledged the pervasive role of educational technology and communication advances in mathematics teaching and learning in the twenty-first century. In a press statement describing the release of *Principles and Standards for School Mathematics* (NCTM, 2000), Glenda Lappan, president of NCTM explicitly articulated their stance toward educational technology integration in the following statement:

Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances student learning. It needs to be used wisely, by well-informed teachers, to support understanding (Lappan, 2000).

In the *Principles and Standards for School Mathematics* document, technology represents one of the six overarching themes identified by the mathematics educators: (a) Equity—high expectations for all students; (b) Curriculum—coherent and focused on important mathematics across grades levels; (c) Teaching—understanding what students know and need to learn; (d) Learning—active learning that builds on experience and prior knowledge; (e) Assessment—supporting the learning of mathematics and providing useful information to teachers and students; and (f) Technology—essential in teaching and learning mathematics (NCTM, 2000).

The NCTM standards recognize that technology influences not only how mathematics is taught in the classroom, but also the choice and sequencing of topics (NCTM, 2000). Specific technologies mentioned in the introduction to the standards include dynamic geometry software, spreadsheet technology to organize and analyze large data sets, simulations to study sample distributions and for modeling and solving complex problems, computer representations for the study of linear relationships, and calculator-based-laboratory systems. The NCTM standards suggest that students in secondary school develop computer fluency in the context of mathematics by using spreadsheets and data-gathering devices with graphical programs to analyze large data sets such as school, state or federal budgets, and mutual funds or used car prices.

Table I. NCTM Standards 2000: Explicit References to Use of Educational Technology

Standard	#	Examples of explicit references
1. Number and operations	2	– Calculators should be available at appropriate times as computational tools, particularly when many or cumbersome computations are needed to solve problems
2. Algebra	3	– They should develop fluency in operating with symbols in their high school years, with by-hand or mental computation in simple cases and with computer algebra technology in all cases.
3. Geometry	5	– Technology also has an important role in the teaching and learning of geometry. Tools such as dynamic geometry software enable students to model, and have an interactive experience with, a large variety of two-dimensional shapes.
4. Measurement	0	
5. Data analysis and probability	2	– As students deal with larger or more-complex data sets, they can reorder data and represent data in graphs quickly, using technology so that they can focus on analyzing the data and understanding what they mean.
6. Problem solving	0	
7. Reasoning and proof	2	– Students at all grade levels should learn to investigate their conjectures using concrete materials, calculators, and other tools, and increasingly through the grades, mathematical representations and symbols.
8. Communication	2	– Students will profit from experiences that require comparisons of standard mathematical expressions with those used with popular tools like spreadsheets or calculators.
9. Connections	1	– Students in grades 3–5 can use the Internet to collaborate with students in other classrooms to collect and analyze data about acid rain, deforestation, and other phenomena. By grades 9–12, students should be able to use their knowledge of data analysis and mathematical modeling to understand societal issues and workplace problems in reasonable depth.
10. Representation	6	– Technological tools now offer opportunities for students to have more and different experiences with the use of multiple representations. – Computers and calculators change what students can do with conventional representations and expand the set of representations with which they can work. – Technological tools now allow students to explore iterative models for situations that were once studied in much more advanced courses.

The role of algebra in computing and business modeling to solve scheduling problems or handle financial decisions illustrates another technology-mathematics application. The NCTM drives home the importance of both mathematics and technology literacy by integrating educational technology as a critical element in the *Standards 2000* document.

The NCTM Standards identify five content and five process standards in mathematics. A review of these 10 standards indicates explicit reference to instructional technology use for 8 of the 10 identified standards. Table I identifies the standards, indicates the number of times instructional technology is explicitly described within that standard and provides sample reference statements from the *Standards 2000* document.

At the NCTM web site, an electronic version of the *Principles and Standards for School Mathematics* document includes examples designed to demonstrate to teachers the particular themes discussed in various sections of the manuscript. Table II identifies the educational technology lessons found on the NCTM web site to provide teachers examples of appropriate uses of educational technology to teach mathematics.

Thus, the *Standards 2000* document not only embeds technology within mathematics instruction and learning, the web site models the use of educational technology for secondary mathematics teachers. The NCTM standards insert educational technology within the mathematics content and provide a clear vision of technology integration for mathematics teachers.

Educational Technology in the Science Standards

The National Research Council published the most recent national standards for science education in 1996. Several important scientific organizations contributed to the publication of this document, the *National Science Education Standards* (NSES). In 1989, the American Association for the Advancement of Science (AAAS, 1993) defined scientific literacy through its *Project 2061* publication *Science for All Americans* (Rutherford and Ahlgren, 1990). Three years later, the National Science Teachers Association (NSTA, 1992) published *The Core Content* as part of its *Scope, Sequence, and Coordination* project. After a unanimous vote of the NSTA board in the spring

Table II. NCTM Standards 2000 Electronic Lesson Examples

Grade level	# Lessons	Electronic lesson titles	Type of technology
PreK-Grade 2	6	- Creating, Describing, and Analyzing Patterns to Recognize Relationships and Make Predictions	Interactive figures
		- Investigating the Concept of Triangle and Properties of Polygons	Interactive geoboards
		- Learning Geometry and Measurement Concepts by Creating Paths and Navigating Mazes	Interactive figures
		- Developing Geometry Understandings and Spatial Skills Through Puzzlelike Problems with Tangrams	Computer "shape" environments
		- Learning about Number Relationships and Properties of Numbers Using Calculators and Hundred Boards	Virtual 100 boards and calculators
		- Number, Geometry, Measurement, and Data Concepts	Multipart video examples
Grades 3-5	5	- Communicating about Mathematics Using Games	Interactive games
		- Understanding Distance, Speed, and Time Relationships Using Simulation Software	Software simulation
		- Exploring Properties of Rectangles and Parallelograms Using Dynamic Software	Dynamic geometry software
		- Accessing and Investigating Data Using The World Wide Web	Data sets available on the Internet
		- Collecting, Representing, and Interpreting Data Using Spreadsheets and Graphing Software	Spreadsheets and graphing software
		- Learning about Multiplication Using Dynamic Sketches of an Area Model	Interactive figures
Grades 6-8	6	- Learning about Rate of Change in Linear Functions Using Interactive Graphs	Interactive graph
		- Learning about Length, Perimeter, Area, and Volume of Similar Objects Using Interactive Figures	Dynamic figures
		- Understanding Congruence, Similarity, and Symmetry Using Transformations and Interactive Figures	Interactive figures
		- Understanding the Pythagorean Relationship Using Interactive Figures	Visual and dynamic demonstrations
		- Comparing Properties of the Mean and the Median Through the Use of Technology	Interactive software
		- Learning about Properties of Vectors and Vector Sums Using Dynamic Software	Dynamic geometrical representations
Grades 9-12	5	- Using Graphs, Equations, and Tables to Investigate the Elimination of Medicine from the Body	Interactive graphical analysis
		- Understanding Ratios of Areas of Inscribed Figures Using Interactive Diagrams	Dynamic & interactive geometric figures
		- Understanding the Least Squares Regression Line with a Visual Model	Visual models
		- Exploring Linear Functions: Representational Relationships	Linked representations of linear functions

of 1991, the NSTA president solicited the help of the National Research Council (NRC) in coordinating a project to develop a set of NSES. While working on their *Benchmarks for Science Literacy* (AAAS, 1993) project, members of the AAAS committee provided the NRC with a working draft of their benchmarks that contributed to and helped to shape the NSES. Support from presidents of leading science and science education associations as well as other interested parties led to funding for the project by the Department of Education (DOE) and the National Science Foundation (NSF).

A committee established by the NRC administered the project with the aid of an advisory committee of representatives from the NSTA, AAAS, American Chemical Society (ACS), National Science Research Council (NSRC), American Association of Physics Teachers (AAPT), Council of State Supervisors, Earth Science Education Coalition (ESEC), and the National Association of Biology Teachers (NABT). Initial work on the standards project began in May 1992 and continued through the fall of 1993. In May 1994, the committee released a preliminary draft of the standards to a selected set of individuals

representing each of the organizations involved in the project for review and comments. After extensive revision, the group distributed new drafts to some 18,000 individuals and 250 groups for additional review. The NRC published the final NSES document in 1996. The NSES identify six general areas of interest: (a) Science Teaching Standards—what science teachers should know and be able to do; (b) Professional Development Standards—how professional development should impact teachers; (c) Assessment Standards—criteria to judge the quality of assessment practices; (d) Science Content Standards—what students should know, understand, and be able to do in K-12 classrooms; (e) Science Education Program Standards—describe quality school science programs; and (f) Science Education System Standards—describe criteria for quality science education systems.

Before reviewing the vision offered for educational technology in the NSES, the definition of technology requires some clarification. Technology, to a scientist, refers to much more than classroom uses of calculators, computers, or other electronic devices. As used in the NSES *Standards*, technology is a specific topic in science instruction and therefore, is treated as an instructional outcome. For instance, the central distinguishing characteristic between science and technology is a difference in goal: The goal of science is to understand the natural world, and the goal of technology is to make modifications in the world to meet human needs. Technology as design is included in the *Standards* as parallel to science as inquiry. The use of “technology” in the *Standards* is not

to be confused with “instructional technology,” which provides students and teachers with tools—such as computers to conduct inquiry and to understand science (NRC, 2000). The historical meaning of technology as knowing how to do things represented by the practical arts or their study has clearly been replaced by a much wider connotation in modern days. Although for science teachers and scientists, technology embraces a much broader panorama than simply educational technology, for the purposes of this analysis, the NSES was examined for explicit references to the use of educational electronic technologies.

A search through the NSES to identify the vision provided for educational technology use in science teaching finds few explicit references. In the Science Content Standards, the NSES suggest the use of educational technology tools to gather data and extend the senses. The standards describe how students might collect, summarize, and display data in inquiry lessons. In addition, at the 9–12 level in the chapter on Science and Technology, the standards describe models, simulations and the use of computer software as part of the process of technological design (NRC, 1996). Table III summarizes the explicit references that offer a vision to science educators for educational technology use in the NSES. No mention of educational technology use occurs in sections of the Content Standards for Physical Science, Life Science, Earth and Space Science, Science in Personal and Social Perspectives and the History and Nature of Science for any of the three grade-level groupings (K-4, 5–8, 9–12).

In the discussion of resources needed for science education programs, the NSES mention the

Table III. Explicit References to Educational Technology in the National Science Education Content Standards

Grade level & standard	#	Examples of explicit references
K-4		
Science as inquiry	1	– Students will also develop skills in the use of computers and calculators for conducting investigations
5–8		
Science as inquiry	1	– The use of computers for the collection, summary, and display of evidence is part of this standard. Students should be able to access, gather, store, retrieve, and organize data, using hardware and software designed for these purposes
9–12		
Science as inquiry	1	– A variety of tools such as hand tools, measuring instruments, and calculators should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard
Science and technology	2	– Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes – A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials such as wood, metal, plastics, and textiles. Solutions can also be implemented using computer software

Table IV. National Science Education Standards Educational Technology Examples

Grade level	Lesson title	Educational technology
K-4	Earthworms	None
	Science Olympiad	None
	Musical Instruments	None
	Willie the Hamster	None
	Weather	Computer data logging; spreadsheets; graph making
5-8	Weather Instruments	None
	The Insect and the Spider	None
	Pendulums	None
	Funny Water	None
	The Egg Drop	None
	The Solar System	None
9-12	Fossils	None
	Photosynthesis	None
	An Analysis of a Scientific Inquiry	None
	Genetics	Computer simulation for iterative breeding cycles

use of educational technology for tutorial purposes for students in need of individualized instruction. In addition, when describing the materials and supplies needed for the science classroom, NSES standards name computers with software as necessary for supporting inquiry investigations. The NSES also mention the desirability of classroom communication technology to help students access other students and scientists throughout the world (NRC, 1996).

To provide a vision for classroom teachers to implement the NSES in their planning and teaching, a set of exemplary lessons offers snapshots of the inquiry-based classrooms necessary to prepare a scientifically literate population. A check of these exemplary lessons reveals that of the 15 presented, only 2 include the use of educational technology (see Table IV). In a genetics lesson intended for secondary students, the standards propose teachers use simulation software to observe rapid iterative breeding cycles in order to establish family pedigrees. The second example suggests the use of spreadsheet software to create graphs in a weather lesson for fourth graders. Interestingly, another lesson modeled in the standards (Fossils) includes a graphical analysis segment, but fails to recommend the use of electronic graphing programs.

In summary, while the NSES clearly include technology as design as an important focus for science education, the technology definition referred to in the standards embraces a broader view than educational technology. The NSES focus more on the goal of developing understandings of the relationships between

science and technology than it does on providing teachers with a vision of educational technology integration in science teaching. Teachers looking for a vision of appropriate uses of educational technology for classroom science teaching find little guidance in the NSES. The NSES point the way for teachers to achieve scientific literacy for all Americans and provide a road map to guide our nation's teachers. However, the vision they offer for classroom teaching provides few models of appropriate and effective uses of educational technology in science teaching and learning. For science educators searching for a vision of appropriate uses of educational technology in science teaching, the NSES fail to deliver.

National Educational Technology Standards (NETS) for Students

The International Society for Technology in Education (ISTE) published technology standards for students in 1998 describing what students should know and be able to do with educational technology. These standards addressed stakeholders in the preK-12 educational audience interested in promoting the effective use of technology to facilitate school improvement. The initiative for the ISTE-NETS project originated from the ISTE Education's Accreditation and Professional Standards Committee and was funded by the National Aeronautics and Space Administration (NASA), the U.S. Department of Education, the Milken Exchange on Education Technology and Apple Computer, Inc. In addition to

the NETS project, the ISTE Accreditation and Professional Standards Committee developed standards for accreditation of preservice teacher preparation programs, guidelines for the infrastructure needed to support technology application in preservice teacher education programs, and general standards for technology use for all teachers.

The NETS document development and review process took place from 1994 to 1998. After release of the 1998 NETS for students, the NETS Project Leadership Team together with their contacts in various curricular fields and project partners collected names of teachers, teacher educators, and curriculum and technology coordinators who had demonstrated exemplary use of technology in teaching and learning. From this pool of candidates, the NETS Project Leadership team selected members for the Writing Team and invited them to participate in a weeklong meeting to produce the *National Educational Technology Standards for Students: Connecting Curriculum and Technology*. Smaller multidisciplinary writing teams drawn from this group fashioned units of instruction that knit technology into different curriculum areas. In addition, focus groups across the United States commented on the usefulness, appropriateness, and curricular content of the lessons. The final project, *NETS Standards for Students: Connecting Curriculum and Technology* published in 2000 represents the collaborative work of more than 2000 individuals.

The *NETS Standards for Students: Connecting Curriculum and Technology* includes four sections. The first section describes essential conditions for technology integration to succeed, explains what curriculum integration of technology means, details the development process for the book, and offers “How to” tips for the rest of the standards document. The second section describes the technology standards for

students and includes profiles for technology literate students at different levels from PreK-2 up to grades 9–12. Sections 3 and 4 (which represent the bulk of the text) include exemplary lessons modeling educational technology use created by the curriculum writing teams.

The six technology standards identified in the ISTE-NETS for students include one focusing on basic educational technology operations, a second stressing social, ethical, and cultural issues and four standards that relate to communication and productivity aspects of technology use: (a) Basic Operations and Concepts: student understanding and proficiency with technology systems; (b) Social, Ethical and Human Issues: ethical, cultural, and societal issues as well as responsible use and positive attitudes; (c) Technology Productivity Tools: use technology tools to enhance learning, productivity, creativity and collaboration; (d) Technology Communication Tools: use a variety of technology media and formats to collaborate, publish, and communicate; (e) Technology Research Tools: use technology tools to locate, evaluate, collect information, process data, report results, match information resources, and tasks; (f) Technology Problem-solving and Decision-making Tools: use technology resources to solve problems and make informed decisions about real world problems (NETS, 2000, p. 14).

In the third and fourth sections of the ISTE-NETS standards document, model lessons demonstrate technology integration in English, foreign language, mathematics, science, social studies, and multidisciplinary resource units (see Table V). For each discipline except foreign languages, the ISTE-NETS standards offer two sample lessons for each grade level, preK-2, 3–5, 6–8, and 9–12. The foreign language section provides only a single sample lesson at each grade level.

Table V. Science Lesson Plans in the National Educational Technology Standards

Grade level	Lesson title	Educational technology
PreK-2	Classify Animals	Word processing, multimedia authoring, Internet web sites
	Home Sweet Home	Kid Pix Studio, HyperStudio, Web workshop, Digital camera, Video camcorder
3–5	Who's Who in Fingerprinting	Word processing, spreadsheet, graphing, scanner
	World Wide Weather	Multimedia presentation, Internet web sites, E-mail
6–8	Bird Rap—A Web Guide to Local Birds	Word-processing, graphing, web page creation, concept-mapping, video camcorder, digital camera, scanner
9–12	Earth Movement in Real Time	Word processing, spreadsheet, graphing, web sites
	Acceleration	Web page creation, spreadsheet, web site
	How Big Are We?	Presentation software, spreadsheet, web sites

Comparison of Mathematics, Science, and Educational Technology Standards

A comparison of the NCTM (2000), NRC (1996), and NETS (2000) standards reveals fundamentally different visions for the inclusion of educational technology in the classroom. Not surprisingly, the NETS standards include a rich array of educational technology use targeted toward specific content applications across the curriculum. Sample lessons for all disciplines, including mathematics and science, offer the promise of a transforming effect on classroom instruction and student learning processes. Big themes highlight these standards: communication, creativity, data analysis, research, synthesis of ideas, evaluation, and collaborative student-centered learning environments.

The mathematics standards, while obviously focused on mathematics concepts, explicitly embrace the use of educational technology in all aspects of mathematics instruction. From the inclusion of a writing team focused on maximizing the power of new technologies to inform teacher practice in mathematics instruction to the modeling of technology uses in examples throughout the standards, there can be no question that the National Council of Teachers of Mathematics fully intend to provide our nation's students with twenty-first century educational technology embedded in the context of mathematics.

In contrast, the NSES clearly distinguish between the importance and centrality of technology as design and the use of educational technologies in the classroom. Unlike the mathematics standards, the science document makes few references to the use of educational technology in science classrooms. The scant mention and modeling of educational technology throughout the NSES document offer teachers a limited vision of educational technology use in school science instruction.

EDUCATIONAL TECHNOLOGY IN NATIONAL SCIENCE AND MATHEMATICS ASSESSMENTS

If it is important for students to know and be able to do something, then it is reasonable for national standardized assessments to provide a vision of how educational technology skills should be tested. Teachers consider the skills required by national assessments that will be used as university admissions criteria for their students or for preservice teachers to

obtain certification when making daily choices about what to include and what to exclude from their lesson plans. If students need to know how to handle large data sets and manipulate spreadsheets for national tests, then teachers will find time in their lessons to include these skills. To date, handheld electronic calculators represent the only kind of educational technology allowed by national standardized tests used throughout the United States for college admissions (SAT and ACT), college credit (Advanced Placement – AP), or for state teacher licensing decisions (Praxis). Table VI presents an overview of calculator policies for these four national standardized test instruments. While few would be surprised that electronic calculators are not permitted during biology or earth science tests, the quantitative nature of chemistry and physics suggests that calculators might be useful during problem solving in these disciplines.

It is important to note, that when calculator use is permitted, recommended, or required, testing policy strictly defines and limits the types of calculators students may use. Technologies specifically excluded include pocket organizers, handheld or laptop computers, electronic writing pens or pen-input devices, wireless communication devices, and QWERTY keypad devices (ACT, 2003; College Board 2003a,b,c,d,e,f,g,h; Dion *et al.*, 2001; Educational Testing Service, 2003).

Even excluding the biology and earth science tests from consideration, the calculator policies for assessments in mathematics and science topics differ strikingly. While SAT I, SAT II, ACT, AP, and Praxis exams allow calculator use during most mathematics exams, only portions of the AP examinations in chemistry and physics permit the use of calculators. It is also interesting to note that calculator use is required for test-takers on the SAT II mathematics subject tests, the 0061, 0063, and 0064 Praxis mathematics exams, and parts of both the multiple choice and free response sections of the AP calculus exams.

In summary, national assessments used throughout the United States for student college admissions (SAT and ACT), college credit courses taken at the secondary level (AP classes), and teacher licensure programs (Praxis) encourage and sometimes require candidates to use electronic calculators in most tests of mathematics content. However, the only science content assessments that allow calculator use are the free response questions on the Advanced Placement chemistry and physics exams. No national standardized science assessment recommends or requires the use of handheld electronic calculators.

Table VI. Summary of Calculator Policy on SAT, AP, and Praxis Testing in Science and Mathematics

Standardized tests	Calculator policy	
Scholastic Aptitude Tests		
SAT I: Mathematics	Recommended	
SAT II: Mathematics	Required	
SAT II: Biology		Not permitted
SAT II: Chemistry		Not permitted
SAT II: Physics		Not permitted
ACT Assessment Test		
Mathematics	Permitted	
Science Reasoning		Not permitted
Advanced Placement tests		
AP Calculus: AB and BC		
	Multiple choice	
	Part A	Not permitted
	Part B	Required
	Free response	
	Part A	Required
	Part B	Not permitted
AP Chemistry		
	Multiple choice	Not permitted
	Free response	Permitted
AP Physics		
	Multiple choice	Not permitted
	Free response	Permitted
AP Biology		Not permitted
Praxis Series 2001–2002		
0730 I: Preprofessional Skills Test (PPST Math)		Not permitted
0060 Mathematics	Permitted	
0061 Mathematics: Content knowledge	Required	
0063 Mathematics: Proofs, models, and problems, Part 1	Required	
0064 Mathematics: Proofs, models, and problems, Part 2	Required	
0065 Mathematics: Pedagogy		Not permitted
0067 General mathematics		Not permitted
0069 Middle school mathematics	Permitted	
Biology tests		Not permitted
Chemistry tests		Not permitted
Earth Science tests		Not permitted
General Science tests		Not permitted
Physical Science tests		Not permitted
Physics tests		Not permitted

CONCLUSIONS

From the development of writing to the invention of the printing press and the computerization of the information age, the culture of information has impacted the way we learn and make sense of the world. Educational systems that fail to respond to cultural changes that accompany advancing technology will find it difficult to compete in a global society. The standards movement hopes to promote educational reform in order to better educate and prepare America’s school children for the workplace of the new century. To meet the goals established by Riley’s *e-Learning: Putting a World-Class Education at the Fingertips of All Children*, teachers must learn

to use educational technology effectively to help students reach high academic standards, educators must point the way with effective next generation technology applications for teaching and learning, and digital content and networked applications must become a normal aspect of modern schools. Embedding educational technology in content standards for teaching and learning positions them where they can be most effective for the classroom teacher, connected to the content they plan to teach.

The NETS standards attempt to point the way for content area integration of educational technology by modeling many individual and multidisciplinary sample lessons. While the NETS standards for

educational technology use offer a wide variety of lessons, it is unlikely that classroom teachers will be exposed to them. The revised *National Council of Teachers of Mathematics 2000 Standards* embrace and embed modern educational technology in mathematics teaching, modeling appropriate and effective methods to incorporate technology in daily lessons. However, the NSES offer only a limited vision of educational technology use in the science classroom. Mathematics teachers who use the NCTM standards will find a rich vision of educational technology uses for classroom use. Science teachers who use the NSES will find little help in integrating educational technology in their lessons.

Assessments exert a profound influence on what teachers choose to teach and students choose to learn. As the NSES point out, "Assessment practices and policies provide operational definitions of what is important" (NRC, 1996, p. 76). Assessments that recommend or require students to use electronic calculators in problem solving are currently in use for many mathematics tests for college admissions, college advanced placement credit and teacher licensing exams. In contrast, assessments in quantitative science disciplines such as chemistry and physics do not allow the use of calculator technology except for the free response sections of the AP exams in chemistry and physics. If teachers truly teach to the test, then these national standardized tests provide high motivation for mathematics teachers to include electronic calculators as part of their classroom teaching and little to no motivation for science teachers to incorporate educational technology in their daily lessons.

In summary, the *NCTM Standards 2000* document and national assessments provide a rich vision to mathematics teachers for the use of educational technology in teaching and learning. The NRC (1996) document and national assessments in science offer little vision to science teachers for the use of educational technology in teaching and learning.

RECOMMENDATIONS

If educators support the national goals for educational technology education in American schools, then educational standards in all disciplines should be written to explicitly model appropriate inclusion of educational technology. While the mathematics standards have already taken this progressive step, future iterations of the NSES should offer a clear vision to classroom teachers for appropriate educational tech-

nology use for science teaching in twenty-first century classrooms.

In addition, assessments for college admissions, for college credit courses, and for teacher licensing need to address the use of appropriate educational technology in problem solving in science as well as mathematics. Assessments that require students to use educational technology to analyze and evaluate data will drive classroom teaching that encourages students to analyze and evaluate data.

Science educators need to identify and model effective and appropriate uses of educational technology in science teaching in university science methods classes as well as in K-12 classrooms. Future science teachers should explore, develop lessons, and practice teaching with educational technology to enrich the learning experiences of their students. Science educators who expect to prepare science teachers for the technology-rich classrooms of the twenty-first century need to encourage all sectors of the educational community to help students learn to use and apply the powerful tools of the information age.

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