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ASSESSING THE EDUCATIONAL TECHNOLOGY PROFICIENCY OF STUDENTS AND EDUCATORS

A REVIEW OF CURRENT POLICY, PRACTICE, AND RESEARCH – FINAL REPORT

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Introduction

Technology proficiency is a critical component of students' readiness for effective participation in the 21st century economy (e.g., Bailey, 1990; CEO Forum, 2001; Drucker, 1994; Perelman, 1992; Reich, 1992; U.S. Department of Labor, 1991). Workers across many sectors of the economy will be "technologists" (Drucker, 1994) who operate the computer-based machines that pervade all industries or "symbolic analysts" (Reich, 1992) who use technology to create knowledge and manipulate digital information. In post-secondary education, technology proficiency is ever more essential for success, where course Web sites, e-mail, computer-based research tools, and word processing are becoming standard features of general education. Technology-supported lifelong learning is seen as critical to staying effective in the world of work (Perelman, 1992; Reich, 2001; Scardemalia & Bereiter, 1996).

The increasing availability of educational technology and digital content are also transforming K-12 teaching and learning (e.g., Dede, 2001; Papert, 1993). In U.S. schools, computer and Internet access increased sharply throughout the late 1990s and continue to increase. The U.S. Department of Education reports that as of fall 2000, 98 percent of public schools were connected to the Internet, a dramatic increase over 1994, when just 35 percent of schools were connected. A sharp rise in school connectivity occurred recently, with 77 percent of instructional rooms connected to the Internet, compared to 63 percent in 1999. In 1994, only 3 percent of instructional rooms were connected (Cattagni & Farris, 2001).

Technology Proficiency Assessment: What and How?

In this context, there is little question that schools need to prepare students to be proficient with technology, and that educators need to be ready to integrate technology into the curriculum. However, other questions remain: What kind of technology-related proficiencies should students be acquiring in schools? Should all secondary students acquire the same technology skills, or should technology proficiencies be specified for different career trajectories? What approach should states and districts take to set standards for technology proficiency, so that students who begin high school today prepare to master the technologies of tomorrow?

Given the importance of technology proficiency in students' lives and futures, knowing what students know about technology and assessing students' readiness to learn and work with technology are increasingly important. Clearly, it is important for policy-makers, educators, parents, and students to know that all students are acquiring the technology-related skills and knowledge they need in order to participate successfully in the 21st century workforce and to be autonomous, life-long learners. State and federal agencies need to determine the prevalence of technology proficiency among students to assure the availability of a technologically skilled work force. Technology proficiency assessments are needed in school accountability systems so that educators and policy-makers can determine whether schools are adequately preparing all students to participate effectively in the workforce.

However, large-scale assessment of technology proficiency is relatively new. As technology proficiency as a domain of learning continues evolve and as technology proficiency becomes more important for students education and work force participation, key questions about assessment of proficiency with educational technology need to be addressed. How is educational technology proficiency currently being measured for students? For teachers? How adequate are current measures for the kinds of decisions are based on them, at local, state, and federal levels? These and other questions need to be addressed as technology proficiency standards and assessments are developed and deployed by states and districts.

It is possible to collect such data in a variety of ways. Relevant data can be generated from so-called proxy measures, such as course-completion rates (in secondary schools and teacher training programs). Self-report measures (questionnaires) are in wide use, especially as used by teachers for professional development planning and evaluation. Portfolio assessments are also widely used in teacher training programs in some states (such as North Carolina), and are being used in a supporting role in large-scale student assessments in some states (e.g., the Vermont and Kentucky state-wide assessments; Reckase, 1995), and are favored by some because they can more easily incorporate "authentic" tasks that have high similarity to classroom and "real world" tasks. In the context of large-scale assessment, direct measures, including multiple choice tests and performance assessments, are generally seen as providing the most valid and reliable data on the actual levels of proficiency attained by individuals (Chronbach, 1990). Each type of assessment has its legitimate uses and its strengths and limitations for specific purposes, and all instrument types can have better or worse technical quality (validity and reliability).

Two crucial issues in assessment and accountability are (1) to develop and use assessment instruments that can yield data of adequate quality for the purposes the data are used for, and (2) to deploy assessments in the context of accountability systems that meet the standards of practice for educational assessment and that are sensitive to local needs and contexts. In the enterprise of assessing educational technology proficiency, educators and policy-makers face the challenge of clarifying what skills and knowledge should be assessed and assuring the development of measurement instruments of high enough technical quality to produce valid and reliable data and suitable for use in accountability systems.

Two key challenges in the development and implementation of technology proficiency standards and assessments are critical to address. First, technology proficiency is a moving target, and therefore skills and knowledge, as well as assessment approaches, have changed, and will most likely continue to change, comparatively rapidly. As an example of this, an early national assessment of educational technology, the 1985-86 administration of the National Assessment of Educational Progress assessed technology proficiency in three areas: (1) knowledge of computer set ups; (2) understanding of computer applications; and (3) understanding of computer programming (Martinez & Mead, 1988). Today, 17 years later, the first and third areas, as defined and operationalized in NAEP, largely do not figure in most current standards. The contrast between the rapid rate of technology innovation and the comparatively slow rate of both assessment and accountability development poses a challenge: Once standards and assessments are developed, if they do not also change rapidly, it will be difficult for curricula to keep pace with the demands of industry, and students may be at risk of being insufficiently prepared for jobs and post-secondary education. However, in a democratic context, the development of educational standards is deliberative and, perhaps inevitably, slow and cannot be easily influenced by the "pull" of technology.

Second, technology proficiency is still ill defined. A variety of approaches to conceptualizing the domain exist, although, within the relatively small research literature in the domain, there is little consensus on how technology proficiency should be defined. Even less clear is the issue of how technology proficiency should be formulated into standards. The relative merits of the one-size-fits-all approach and alternatives to it are little discussed. However, it is quite possible, given the enormous diversification of technology in society, that at the secondary level, a range of technology proficiency standards could be relevant for different students. Educators, then, are faced with the need to achieve consensus in defining the domain of technology proficiency, and then to, comparatively frequently, reassess this definition and arrive anew at consensus. Given the rapid rate of technology, for assessment, "the challenge in this domain is to think about testing that can predict technological fluency for technologies and environments not yet conceived" (Becker & O'Neil, 1998, p. 39).

Technology proficiency is still a young domain (about two decades old), having only recently grown beyond its "computer literacy" infancy, and many states are still in the process of formulating standards. However, in response to the increasing pervasiveness of technology in the worlds of work and education, many states have established standards for educators and students related to educational technology proficiency. A few states are currently assessing students' technology proficiency as part of the states' accountability system, and more states plan to do so. It seems apparent that states' efforts to create standards and assessments for students' and educators' educational technology proficiency will continue to develop. However, there exists little research in the domain of technology proficiency and its assessment to guide these developments. While various conceptions of technology proficiency exist, and a variety of organizations have developed standards for students and teachers related to technology, there is considerable diversity in conceptualizations and standards, and little research to guide further development in the field. In addition, through our extensive review of technology proficiency assessment instruments currently available for teachers and students, we have found few instruments suitable for use in large-scale assessment.

The increasing importance of technology proficiency for students and teachers has led to the need for high quality direct assessments for both populations. A variety of assessment types, such as direct (cognitive) measures, performance assessments, and portfolios, can be suitable for collecting data for different purposes. However, federal agencies, states, districts, parents, and other stakeholders need *reliable* data that students and teachers are acquiring the knowledge and skills needed for the worlds of work and education. Furthermore, as states adopt standards for technology proficiency, assessments are needed for the accountability systems that track achievement against standards.

This report examines these issues and other aspects of the current "lay of the land" in the domain of policy and practices in educational technology proficiency standards and assessment, and lays out issues and questions that need to be addressed as states move forward in these areas. It focuses on the use of direct measures of technology proficiency (as opposed to self-report measures) and reviews available assessments of educational technology proficiency. In addition, it reviews current state and national standards in the domain of technology proficiency standards, assessment, and accountability.

Background

Emergence of Technology Proficiency as a Skill Area in Schools

In the 1980s, with the advent of computers as a personal technology for work and home use, schools began to address the need to prepare students to use technology. In 1983, the landmark report, *A Nation at Risk*, identified competence with computers as one of the "New Basic" skills needed for workplace readiness. This report recommended that high school students take a half year of "computer science" in order to "(a) understand the computer as an information, computation, and communication device; (b) use the computer in the study of the other Basics and for personal and work-related purposes; and (c) understand the world of computers, electronics, and related technologies" (National Commission for Educational Excellence, 1983).

An influential 1991 U.S. Department of Labor report, *What Work Requires of Schools* (1991; also known as Secretary's Commission on Achieving Necessary Skills [SCANS], 1991), also examined the importance of technology proficiency for workforce readiness. This commission identified technology as one of five key skill areas, or "competencies", that students need in order to more successfully negotiate the transition from school to the workforce. Competence with technology was described in the SCANS report as involving selecting technology, applying technology to tasks, and maintaining and troubleshooting equipment. (These remains the same in the 2000 update of the SCANS skills [http://www.scans.jhu.edu/].)

Based on the SCANS 1991 report and the increasing pervasiveness of computer technology in business, industry, and science, focus on the need for schools to develop students' proficiency with technology intensified in the 1990s. And educators were increasingly able to address student technology proficiency with the massive infusion of technology into schools, especially in the second half of the 1990s.

More recently, an important shift is apparent in some efforts to define technology-related skills that students need to acquire in school. Whereas earlier skill frameworks, such as SCANS, focused on skills and knowledge *with* technology required for the workplace, some of today's work-readiness frameworks address broader and more comprehensive skills that students need to be ready to work in a technology-infused workplace. These include higher order cognitive skills, affective skills and dispositions, habits of mind, and social skills. For example, the North Central Regional Educational Laboratory (NCREL) "enGauge" Web site (http://www.ncrel.org/engauge/) lays out a four-category framework of 21st century work skills that includes digital age literacy, inventive thinking, effective communication, and high productivity. Enumerated skills in these categories include "teaming collaboration, and interpersonal skills", "effective use of real-world tools", visual and information literacy." Such frameworks track well with the 21st century workplace skills identified by Drucker (1994), Peters (1997), and Reich (2001), such as creating, sharing, and mastering knowledge, critically evaluating information, collaborating to accomplish tasks, and "thriving on chaos." However, as Dede (2001) argues, these sorts of higher order cognitive skills and affective dispositions go far beyond the technical skills that some states are beginning to require for teachers. While technical skills, such as mastery of computer productivity applications and design of Web pages, are useful to educators, these competences, according to Dede (2001), should be taught and used in the context of tasks that foster complex, multifaceted personal aptitudes that underlie the workplace skills needed for the 21st century.

National and International Studies of Student Technology Skills

Valuable information about what American students know about and can do with technology has come from several international studies that assessed student proficiency with educational technology. In addition, several international studies are currently being planned by international research bodies and panels.

During the 1985-86 academic year, the National Assessment of Educational Progress (NAEP) conducted the first assessment of students' computer competence (Martinez & Mead, 1988), testing students' skills and knowledge in computing through recall and recognition items on facts, concepts, and procedures related to computer use. The test was taken by students in grades 3, 7, and 11. The test framework divided computer competence into three areas: knowledge of computer technology, computer applications, and computer programming. Test data indicated that while most 11th graders were familiar with the parts of a computer, only a small fraction of them were able to answer questions about computer applications or computer programming.

The national assessment has not been repeated, although an international assessment of computer competence has been conducted (Pelgrum & Pompt, 1993; Pelgrum, Reinen, & Plomp, 1993). The International Association for the Evaluation of Educational Achievement's (IEA) 10-nation study on computers in education examined, among other topics, the relationships between variables related to school, teacher, and classroom practice and student outcomes such as functional computer literacy and performance in handling computers. To assess student IT-related skills and knowledge, researchers designed the Functional Information Technology Test (FITT; see Student Instrument Matrix in Appendix), a 30-item paper-and-pencil, selected-response (multiple choice) test. The framework for this assessment encompassed basic concepts of information processing, information handling, computer applications, and computer functioning. Sample questions are: What are BASIC, Pascal and LOGO?; What does a cursor do?; Sorting a pile of books in an alphabetic order by name of author is an example of: (information processing).

The study found that FITT scores for American elementary students were low. An accompanying survey found that students received almost no direct instruction on content covered on the test, indicating that students were learning what they did know about computers outside of school (Pelgrum, Reinen, & Plomp, 1993, pp. 53-54). Lower secondary American students scored in the lower half of seven countries for which opportunity to learn data is also available (Austria, Bulgaria, India, Japan, Latvia, Slovenia, and the U.S.) Upper secondary American students had the third highest scores among the seven countries.

A planned international assessment of technology proficiency, IEA's Module 3 of the Second Information Technology in Education Study (SITES M3), will mark a significant expansion of educational technology proficiency assessment, from a more narrow focus on assessment of technology-related skills to assessment of skills in science and math *using* technology. Underlying this shift is the view that new educational technologies, such as those that support data visualization and modeling, have the potential to reconfigure the cognitive dimensions of tasks (Kozma & Quellmalz, 2001), and that information and communication technology (ICT) should be used to assess the new intellectual skills involved in content learning and problem solving with these tools.

Other organizations planning to develop international assessments related to technology proficiency are ETS and Organization for Economic Cooperation and Development (OECD). ETS convened an international blue ribbon panel that had its initial organizing and planning meeting in spring 2001. The OECD's series of tests known as the Program for International Student Assessment (PISA) will incorporate a direct assessment of problem-solving as an optional module in its spring 2003 assessment; the associated student questionnaire will collect information related to students' familiarity with ICT.

Key Policies and Resources That Support Teacher Technology Proficiency

An important aspect of developing students' technology proficiency is addressing pre-service and in-service teachers' technology proficiency and preparing them to integrate technology into the curriculum. Twenty-two states currently have technology standards for teachers and require technology proficiency to be demonstrated at various junctures, such as at isnitial hiring or credentialing. States' efforts to promote teacher technology proficiency are supported by the efforts of various organizations in the fields of teacher preparation and educational technology, including the National Council for Accreditation of Teacher Education (NCATE) and ISTE.

NCATE is the primary accrediting agency for teacher training programs. Its accreditation criteria address the incorporation of technology and technology proficiencies into teacher training programs. NCATE implemented revised professional standards for the accreditation of schools, colleges, and departments of education (SCDEs) in fall 2001. According to NCATE's accreditation requirements, teacher training programs must meet six accreditation standards. Across NCATE's these standards, the theme of technology proficiency is evident. However, the standards do not specify areas or levels of technology proficiency that must be learned or demonstrated by graduates. Rather, NCATE assumes that teacher training programs develop or identify appropriate standards for teacher and administrator technology proficiency. Requirements from the NCATE standards relating to technology proficiency are the following:

Standard 1: Candidate Knowledge, Skills, and Dispositions, requires teacher candidates to integrate technology in their practices in order to help student learning.
Standard 3: Field Experiences and Clinical Practices, expects teacher candidates involved in school-based activities to improve their usage of information technology.
Standard 5: Faculty Qualifications, Performance, and Development, requires the faculty who are training teachers to integrate technology into their coursework and to understand assessment technology.

For its accreditation of programs for initial preparation of teachers of educational computing and secondary computer science teachers, NCATE uses International Society for Technology in Education (ISTE's) standards. Programs that prepare teachers of educational computing and secondary computer science teachers and that seek NCATE accreditation must provide courses that cover the ISTE standards. For accreditation of programs that prepare teachers of technology education, NCATE uses curriculum standards prepared by the International Technology Education Association/ Council on Technology Teacher Education (ITEA/CTTE). These standards cover knowledge of technical skills that can be used to teach technology education. Programs that prepare teachers of technology education and seek NCATE accreditation must provide courses that cover the ITEA/CTTE standards.

ISTE, supported by funds from the Preparing Tomorrow's Teachers to Use Technology program, developed technology proficiency standards for teachers and administrators. Its teacher standards have been influential in guiding professional development in technology proficiency as well as in guiding states' development of teacher technology standards. With the adoption of ISTE standards by states and districts, states, districts, and teacher training programs require assessments to ensure that pre-service and in-service teachers are acquiring targeted skills. ISTE is currently developing models for electronic portfolio assessments aligned with its teacher standards and based on the NCATE Specialty Areas Study Board's Principles for Performance-Based Assessment Systems in Professional Education Programs. The series of electronic portfolio models will be Web-based and hosted by EDmin.com (Barrett, n.d.).

Educational Technology on the Horizon

Recent developments in the domain of educational technology are relevant to understanding the context of educational technology proficiency assessment. These include the burgeoning post-secondary "parallel universe" of technical training and certification beyond the walls of traditional two- and four-year colleges and universities, and researchers' adumbrations of the looming technology-driven changes in K-12 instruction and assessment.

Parallel Post-Secondary Universe in IT Skills Certification

A recent report issued by the U.S. Department of Education describes a "parallel post-secondary universe" of industry and professional associations that collectively offer hundreds of different types of certifications in the field of information technology (Adelman, 2000). As many high schools begin to offer industry-aligned and industry-supported technology courses, such as for network administration, that prepare students for certification tests, this parallel post-secondary universe is extending into the secondary school sphere, and may well impact policies and practices related to technology proficiency instruction, standards, and assessment.

Since 1989, this "international IT certification guild" (Adelman, 2000) has created over 300 different certifications. Approximately 2.4 million information technology certifications were awarded worldwide by 2000, about half outside the United States. Little is known about who is earning certifications in the U.S., but the study found that the age distribution of certificate earners is dropping, with fewer holding bachelor's degrees.

Corporations and organizations develop or endorse tests that must be passed (cut scores are stipulated) for certification to be awarded. The report notes three testing companies that play major roles in testing in this field: Prometric, CatGlobal (a division of Houghton-Mifflin), and Virtual University Enterprises (VUE, a division of National Computer Systems). These companies have testing centers around the globe. In addition to industry-sponsored certification testing (and not discussed in this report), other online, computer-related skills tests aimed at the secondary and post-secondary levels are also increasingly available. Companies such as SkillCheck and TeckChek offer online testing of basic computer applications skills and more advanced IT skills.

This "international IT guild" has significance for the domain of K-12 technology proficiency assessment. First, the IT certification industry has already extended its reach into secondary schools. Companies such as 3Com, Cisco, Pacific Bell, and Novell offer network administration and other technical courses in high schools which are designed to lead to certification. Usually these high school courses use the same content that is used in courses taught privately, which are oriented to specific certification tests. At two notable California technical high schools visited recently by an author of this report, teachers report that most students taking industry-designed networking courses take or plan to take the certification tests associated with the courses. Schools can adopt courses that lead to either vendor-neutral or vendor-sponsored IT certifications. Some companies that sponsor these courses have educational programs that offer partnerships with schools and connect with school-to-career programs. These companies offer instructor training and certification, technical support, computer-based curricula, and guidance to students in the certification process.

Second, testing in this industry is largely computerized and competency-based. Because computer-based testing has a natural appeal in the domain of technology proficiency, especially where performance-based measures are valued, the assessment technologies and practices developed in this industry are relevant for the development of K-12 technology proficiency assessments. According to Adelman (2000), "the IT guild has brought competence-based education and performance assessment to a status they have never enjoyed within traditional higher education" (http://www.ed.gov/pubs/ParallelUniverse/ summary.html). This industry has developed rigorous accreditations standards for online testing, and these may provide useful information for the development of technology-supported assessments of technology proficiency.

These developments may have important implications for technology proficiency standards and assessments at the secondary level. The penetration of the "IT certification guild" into the secondary level, along with other technology "specializations", such as multimedia design and computer programming, may be a driver for technology proficiency specialization at this level. Such secondary-level specialization in technology may not jibe well with the "one size fits all" approach in the domain of secondary-level technology proficiency standards and assessments.

Online Testing: Present and Future

The field of educational assessment is being significantly impacted by computer technology, which presents opportunities as well as some challenges for large-scale technology proficiency assessment. Online testing is a burgeoning field, as a variety of trends indicates. Industry-oriented computer- and Web-based assessments are increasingly used. Testing firms such as TeckChek (http://www.teckchek.com/) and SkillCheck (http://www.skillcheck.com/) offer Web-based technology proficiency tests for industry use. Academic testing firms are also increasingly using computer technology for test administration. According to Bennett (1998), in 1997-1998 ETS offered a variety of tests online: GRE General Test, GMAT, Praxis I, SAT I: Reasoning Test, ACT's COMPASS, and the College Board's ACCUPLACER.

Computer technology has the potential to make test development and administration more cost-effective and faster. Automated essay scoring appears to be reliable and makes online essays in assessment more feasible and less expensive (according to a recent debate in the IEEE newsletter). Software tools are available to assessment development and administration, and scoring, such as e-rater (ETS), Intelligent Essay Assessor (University of Colorado; http://www.knowledge-technologies.com/, InQuizit (InQuizit Technologies), PEG (Duke University), and Intellimetric (Vantage Technologies).

States are increasingly using online testing for standardized assessment programs. For example, Virginia has contracted with NCS Pearson to use its TestNav technology to administer high school end-of-course assessments as part of its Standards of Learning testing program. A comparability study, comparing the online and paper-and-pencil administrations of the tests, will be conducted in January 2002, and full implementation of online testing is planned for spring 2003. Eventually, the department expects to use online testing for testing in grades 3, 5, and 8 as well. Georgia has also recently contracted with NCS Pearson to begin online testing for its end-of-course high school tests. Pennsylvania recently began using online testing in its state assessment program, and Oregon and South Dakota have also begun some online testing. Requests for proposal issued by states for standardized testing programs are beginning to include an electronic testing option, an industry insider recently reported. In the United Kingdom, information and communication technology (ICT) skills for both students and teachers are tested online, with the tests offered at computer testing center around the country.

Most relevant to technology proficiency assessment is the potential of computer technology to impact *what* is assessed, in addition to how it is assessed. Some educational technology-related skills, such as the use of visualization and modeling software, may require new approaches and tools to be most reliably assessed (Kozma & Quellmalz, 2001). Beyond technology skills, some educators hold that online assessment offers the potential to move high-stakes testing beyond the relatively narrow set of concepts and skills that can be assessed through paper-and-pencil tests and to begin assessing more complex skills and knowledge (Bennett, 1998). Adelman's report on the "parallel post-secondary universe" (2000) indicates that the IT industry has demonstrated the positive potential of computer-based testing for performance assessments. Online assessment may facilitate the integration of standardized testing into regular classroom activity (Wagner & Vander Ark, 2001). In such a scenario, test data may become more accessible to teachers and students as a source of achievement data. Furthermore, types of assessment other than selected-responses tests, such as portfolios and performance assessments, may be more easily integrated into classroom practice as wesll as district and state accountability systems (Wagner & Vander Ark, 2001). Electronic portfolios and technology-supported performance assessments are likely to be more cost-effective to design, use, and score than their paper-based counterparts.

According to Bennett (1998), "next-generation computer-supported assessments" will be media-rich computer-based tests that allow testing of new skills, such as those related to use of information and communication technologies, technology proficiency, and new media design, as well as more extensive testing of traditional skills. Online testing could also address the limitations of paper-and-pencil-based tests that grow out of the infusion of technology into the curriculum. For example, recent research shows that written tests administered on paper significantly underestimate the achievement level of students accustomed to writing on computers (Russell & Haney, 2000).

However, there are also limitations with administering tests online. Schools' technological infrastructure, which often includes slower computers that do not perform well with current computer software, may not perform adequately and could interfere with testing. Test items must be constructed to accommodate the constraints of the computer screen and variability in computer download and processing speeds (Venezky, 2001; cf. Trotter, 2001). In addition, with the student-computer ratio currently at 5:1 (NCES, 2001), many districts and schools would have difficulties administering online tests simultaneously to multiple grades or even multiple classes. Prior to migrating high-stakes testing online, it is necessary to bring participating schools' technology infrastructure up to standard. The Virginia Department of Education has developed computer and network technology architectural guidelines for high schools implementing online testing (Virginia Department of Education, 2001), which were developed based on its pilot year of online testing and its work with NCS Pearson's TestNav online testing technology.

State Policy and Practices: Technology Proficiency Standards and Assessment for Students and Teachers

This section reviews states; standards, assessment, and accountability policies and practices related to educational technology proficiency for students and teachers. Some information regarding state policy and practice related to technology proficiency standards and assessment is drawn from the Integrated Studies of Educational Technology Survey, which is part of the Technology Literacy Challenge Fund (TLCF) Implementation Study, conducted jointly by American Institutes for Research and SRI International, for the U.S. Department of Education (Adelman, Donnelly, Dove, Tiffany-Morales, Wayne & Zucker, in preparation). Data used in this report were taken from the State Educational Technology Coordinator Survey, Section II: Standards, Assessment, and Integration of Technology. A final report on the TLCF Implementation Study is, at the time of this writing, in preparation .

Student Technology Proficiency Standards and Assessment

A total of 31 states report in the ISETS study that they currently have technology proficiency standards for students. (See Table 1.) Nine states reported having stand-alone technology proficiency standards for students: Alabama, Arizona, Connecticut, Georgia, Montana, Oklahoma, South Carolina, Utah, and Wisconsin. An additional 21 states report that technology standards are integrated with Math and Science across all grade levels, 20 states report integrating technology standards with Language Arts and Social Studies at all grade levels, and 15 states report integrating technology standards into standards for non-core subject areas at all grade levels. At the high school level, 20 states report integrating technology standards into vocational education standards, and 16 report doing so at the middle school level. (One additional state, Nevada, reported having technology proficiency standards, but did not specify whether standards were integrated or stand-alone.)

States report using a variety of sources in developing their student technology standards. Nine states report using adopting technology standards developed by ISTE or another organization for elementary, middle, and high school level standards; of these states, six states have integrated technology standards, and 3 have stand-alone standards. Other states report developing their own technology standards, adapting material from a variety of sources.

Of states with integrated technology standards, 21 states report integrating technology standards with Math and Science, and 20 states reporting integrating technology with Language Arts and Social Studies. (See Table 2.) Fifteen states report integrating technology into non-core subject areas. For vocational education, 16 states report integrating technology standards at the middle school level, and 20 at the high school level. Between 17 and 21 all states , including those with integrated and stand-along technology standards, report covering the following topics in their technology standards at the high school level: basic operations and concepts; social, ethical and human issues; technology productivity tools; technology communications tools; technology research tools; technology problem-solving and decision-making tools. See Table 3.

While 31 states report having either stand-alone (9) or integrated (21) students standards for technology proficiency, only eight states report assessing students' technology proficiency: Arizona, Florida, Hawaii, Louisiana, North Carolina, Pennsylvania, Texas, and Virginia. See Table 4. Of these states, only three states report using a stand-alone paper-and-pencil test or a computerized test to assess technology proficiency at any level: North Carolina, Pennsylvania[1], and Virginia. Of these three, only North Carolina reports assessing technology proficiency at the high school level as state requirement.

Four states, Florida, Hawaii, Louisiana, and Pennsylvania, report that students' technology proficiency is assessed as part of assessments in core academic subject areas at each school level, while four states, Hawaii, Louisiana, Pennsylvania, and Virginia, report assessing technology proficiency as part of assessment in non-core academic subject areas. (See Table 4.)

Several states that assess technology proficiency at least one level also report requiring student to complete a course in technology: Louisiana, Pennsylvania, and Texas. Pennsylvania reports a course requirement at the elementary, middle, and high school levels.

The ISET Survey of State Educational Technology Coordinators also collected data bearing on trends in technology proficiency assessment, querying states' planning or adoption of technology proficiency assessments in the last three year, and changes or planned changes to assessments in core subject areas to use technology or to assess technology proficiency in the last three years. Of reporting states, only six states indicate that a new assessment designed to assess student technology proficiency had been created in the last three years: Hawaii, Louisiana, North Carolina, Utah, Virginia, and West Virginia. (See Table 5.) Four states indicate that changes were

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[1] A conversation with a representative of the assessment department at the Pennsylvania Department of Education, Steve Shimrock, pers. comm., August 7, 2001, indicated that Pennsylvania does not currently assess student achievement in technology. However, the state is in the process of developing a new assessment in science, which may include items that assess technology. The state has technology standards for students that are integrated across core disciplines.

made in assessments in core subject areas in the last three years that related to educational technology: Hawaii, Louisiana, North Carolina, and Utah. Six states indicate that items were added within subject area tests that require the use of technology (Hawaii, New York, Pennsylvania, Rhode Island, Texas, and Utah), while four states indicate that item to assess technology proficiency were added to subject area tests in the last three years (Hawaii, New York, Pennsylvania, Rhode Island).

Teacher Technology Proficiency Standards and Assessment

Although 22 states report having technology standards for teachers, only 11 states indicate that technology proficiency is required at initial hire, and seven indicate that it is required at initial certification or licensure. (See Table 6.) Three states report that a paper-and-pencil or computerized assessment of technology proficiency is required at initial certification (California, Idaho, and Texas), and two states report that such an assessment is required at recertification (Pennsylvania and Texas).

Summary

Technology proficiency standards for students and educators have become common, although independent technology proficiency standards are the exception; of states that have student technology proficiency standards, over twice as many states have integrated standards for technology as stand-alone standards. Assessment of student progress in educational technology mastery is uncommon among states. Assessment of teachers' mastery of educational technology is also rare. In addition, only a handful of states report that changes to tests to address technology proficiency assessments were made or planned in the last three years.

The low prevalence of assessment of student technology proficiency may be a attributable to the relative recentness of state technology initiatives. The general lack of high quality assessments may also discourage state assessment of student technology proficiency; however, state initiatives to assess educational technology proficiency would drive development of such instruments.

Table 1. State Student Technology Standards: Method and Source

	AK	AL	AR	AZ	CT	DC	FL	GA	HI	IL	LA	MA	MD	ME	MI	MO	MT	NC	NE	NJ	NV	OK	PA	RI	SC	TX	UT	VA	VT	WI	WV	TOTAL
State has technology standards for students																																
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	31
Integrated technology standards																																
	X		X			X	X		X	X	X	X	X	X	X	X		X	X	X			X	X		X		X	X		X	21
Stand-alone technology standards																																
		X		X	X			X									X					X			X		X			X		9
State has adopted ISTE's or another organization's technology standards																																
…ES			X						X		X								X			X	X		X		X				X	9
…MS			X						X		X								X			X	X		X		X				X	9
…HS			X						X		X								X			X	X		X		X				X	9
State has developed its own technology standards, which were adapted from various sources																																
…ES	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X		X		X	X	X		24
…MS	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X		X		X	X	X	X	25
…HS	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X		X		X	X	X	X	26

Table 2. Grade levels and subject areas at which state technology standards for students are included

	AK	AR	DC	FL	HI	IL	LA	MA	MD	ME	MI	MO	NC	NE	NJ	PA	RI	TX	VA	VT	WV	Total
Language Arts																						
…in elementary school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	20
…in middle/junior high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	20
…in high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	20
Mathematics																						
…in elementary school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21
…in middle/junior high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21
…in high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21
Science																						
…in elementary school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21
…in middle/junior high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21
…in high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21
Social Studies																						
…in elementary school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	20
…in middle/junior high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	20
…in high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	20
Non-core subject areas																						
…in elementary school	X	X	X	X	X		X	X		X			X	X		X	X	X	X		X	15
…in middle/junior high school	X	X	X	X	X		X	X		X			X	X		X	X	X	X		X	15
…in high school	X	X	X	X	X		X	X		X			X	X		X	X	X	X		X	15
Vocational education																						
…in middle/junior high school	X	X		X	X	X	X				X	X	X	X	X	X		X	X	X	X	16
…in high school	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	20
Other																						
…in elementary school	X				X							X	X	X		X		X		X		8
…in middle/junior high school	X				X							X	X	X	X	X		X		X		7
…in high school	X				X							X	X	X	X	X		X		X	X	10

Table 3. Topics Included in State Student Technology Standards.

	AK	AR	DC	FL	HI	IL	LA	MA	MD	ME	MI	MO	NC	NE	NJ	PA	RI	TX	VA	VT	WV	TOTAL
Standards for technology that states have set for students at different grade levels:																						
Basic operations and concepts E.g., Students demonstrate a sound understanding of the nature and operation of technology systems; Students are proficient in the use of technology																						
…in elementary school	X	X	X	X	X	X	X		X		X		X	X	X	X	X	X	X		X	17
…in middle/junior high school	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X		X	18
…in high school	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X			X	17
Social, ethical and human issues E.g., Students understand the ethical, cultural and societal issues related to technology; Students practice responsible use of technology systems, information and software																						
…in elementary school	X	X	X	X	X	X	X			X	X		X	X	X	X	X	X			X	16
…in middle/junior high school	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X			X	17
…in high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	20
Technology productivity tools E.g., Students use technology tools to enhance learning, increase productivity and promote creativity; Students use productivity tools to collaborate in constructing technology-enhanced models, preparing publications and producing other creative works																						
…in elementary school	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X		X	X	18
…in middle/junior high school	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20
…in high school	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20
Technology communications tools E.g., Students use telecommunications to collaborate, publish and interact with peers, experts and other audiences; Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences																						
…in elementary school	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	20
…in middle/junior high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21
…in high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21
Technology research tools E.g., Students use technology to locate, evaluate and collect information from a variety of sources; Students evaluate and select new information resources and technological innovations based on the appropriateness to specific tasks																						
…in elementary school	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	19
…in middle/junior high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21
…in high school	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21
Technology problem-solving and decision-making tools E.g., Students use technology resources for solving problems and making informed decisions; Students employ technology in the development of strategies for solving problems in the real world																						
…in elementary school	X	X	X		X	X	X			X	X	X		X	X	X	X	X			X	15
…in middle/junior high school	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	19
…in high school	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	20

Table 4. State Assessment of Student Technology Proficiency.

	AZ	FL	HI	LA	NC	PA	TX	VA	Total
States that assess student progress in meeting technology standards	X	X	X	X	X	X	X	X	8
How are assessments conducted?									
Assessment methods are developed/decided upon locally									
…in elementary school	X		X	X	X	X	X		6
…in middle school	X		X	X		X	X		5
…in high school, **but** not a state grad. require.	X		X			X			3
…in high school, **as** a state grad. require.				X	X		X		3
State technology assessment: stand-alone <u>paper-and-pencil</u> test									
…in elementary school						X		X	2
…in middle school					X	X			2
…in high school, but not as a state grad. require.						X			1
…in high school, and as a state grad. require					X				1
State technology assessment: stand-alone <u>computerized</u> test									
…in elementary school						X			1
…in middle school					X	X			2
…in high school, but not as a state grad. require.						X			1
…in high school, **as** a state grad. require.					X				1
Technology items or sections within State assessments in <u>core</u> academic subject areas									
…in elementary school		X	X	X		X			4
…in middle school		X	X	X		X			4
…in high school, but not as a state grad. require.			X	X		X			3
…in high school, **as** a state grad. require.		X							1
Technology items or sections within State assessments in <u>non-core</u> academic subject areas									
…in elementary school			X	X		X		X	4
…in middle school			X	X		X			3
…in high school, but not as a state grad. require.			X	X		X			3
Requiring the completion of a course in technology									
…in elementary school						X			1
…in middle school				X		X			2
…in high school, but not as a state grad. require.				X		X			2
…in high school, **as** a state grad. require.							X		1
	AZ	FL	HI	LA	NC	PA	TX	VA	Total

Table 5. Recent or Planned Changes Related to Student Technology Proficiency Assessment

What changes related to educational technology have been made (or are planned to be made) to State student assessments in educational technology?*		HI	LA	MO	NC	NY	PA	RI	TX	UT	VA	WI	WV
Created a new assessment designed to assess student technology proficiency													
	No change made or planned			X				X	X				
	Made in the past 3 years	X	X		X					X	X		X
Modified grade levels at which technology assessments are done													
	No change made or planned			X	X			X	X		X		X
	Made in the past 3 years	X	X							X			
What changes related to educational technology have been made (or are planned to be made) to State student assessments <u>in core subject areas</u>?													
…Created a new assessment designed to assess student technology proficiency													
	No change made or planned			X		X		X	X		X	X	
	Change made in past 3 years	X	X		X					X			
…Modified grade levels at which technology assessments are done													
	No change made or planned	X	X	X	X	X		X	X			X	
	Change made in past 3 years									X	X		
On existing State assessments in core subject areas:													
…added new items within subject areas that require the use of technology													
	No change made or planned		X		X						X		
	Change made in past 3 years	X				X	X	X	X	X			
…added new items within subject areas that assess technological proficiency													
	No change made or planned		X	X	X					X	X		
	Change made in past 3 years	X				X	X	X					
…offered test via computer in addition to/instead of paper and pencil version													
	No change made or planned		X	X	X	X		X		X			
	Change made in past 3 years	X					X				X	X	
On existing State assessments in non-core subject areas:													
…added new items within subject areas that require the use of technology													
	No change made or planned		X		X			X	X	X	X	X	
	Change made in past 3 years	X		X		X	X						
…added new items within subject areas that assess technological proficiency													
	No change made or planned		X	X	X			X	X	X	X	X	
	Change made in past 3 years	X				X	X						
…offered test via computer in addition to/instead of paper and pencil version													
	No change made or planned		X	X	X			X	X	X		X	
	Change made in past 3 years	X				X	X				X		

* "Don't know" responses (usually two or three states per category) are not included in table.

Table 6. State Standards and Assessments for Teacher Technology Proficiency.

	AK	AR	CA	CT	DC	GA	ID	KS	LA	MD	MI	MS	NC	NE	NJ	PA	SC	TX	VA	VT	WI	WV	Total
State has proficiency technology standards for teachers																							
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	22
When does the State require/recommend teachers to meet state technology proficiency standards?																							
State requires proficiency in technology …																							
… at initial hire			X	X		X	X	X			X		X			X		X	X			X	11
… initial certification or licensure				X		X		X					X			X		X	X				7
At elementary level, teacher technology proficiency is …																							
… needed for license			X			X	X	X	X		X		X			X		X	X	X		X	12
… recommended for license			X			X	X	X	X				X	X	X	X	X		X			X	12
… needed for new contracts				X		X		X					X			X		X	X				7
At middle school level, teacher technology proficiency is …																							
… needed license			X			X	X	X	X		X		X			X		X	X	X		X	12
… recommended for license			X			X	X	X	X				X	X	X	X	X		X			X	12
… needed for new contracts				X		X		X					X			X		X	X				7
At high school level, teacher technology proficiency is …																							
… needed for license			X			X	X	X	X		X		X			X		X	X	X		X	12
… recommended for license			X			X	X	X	X				X	X	X	X	X		X			X	12
Completion of a specific number of hours of technology-related pre-service training or in-service professional development																							
… first certification			X			X	X	X					X			X			X			X	8
… recertification				X		X		X				X	X			X		X					7
Paper and pencil assessment of technology proficiency is required for																							
… first certification			X				X									X							3
… recertification																X		X					2
Computerized assessment of technology proficiency is required for																							
… first certification			X				X									X							3
… recertification																X		X					2
	AK	AR	CA	CT	DC	GA	ID	KS	LA	MD	MI	MS	NC	NE	NJ	PA	SC	TX	VA	VT	WI	WV	Total

Educational Technology Proficiency: Definitions and Standards

The development of standards for educational technology proficiency is hampered by the lack of research in the domain and by the lack of consensus regarding conceptualizations of technology proficiency. Among other things, investigation is needed into such key issues as the developmental trajectories of core technology proficiencies; the developmentally and instructionally appropriate age and grade levels for developing and assessing particular proficiencies; differential post-secondary outcomes for students with different educational technology proficiency levels that may have bearing on the formulation of standards; and what levels of teacher technology proficiency are necessary for effective integration of technology into the core curriculum. In addition, the rapidly changing nature of educational technology and its use in schools poses a challenge to formulating definitions and standards for educational technology. Educators must try to avoid focusing on such narrow or superficial skills and knowledge that standards that are written today will be out of date by the time today's 8th graders graduate from high school.

Existing standards developed by states and national organizations, such as ISTE and ITEA, vary quite markedly in approach and content. Most notably, some states integrate technology standards into core subject area standards while other states have "stand-alone" standards. This difference has significant implications for the eventual construction of data sets that allow the comparison of attainment data across states, as well as implications for the design of assessments. Although the "applications/functional" conception of technology proficiency predominates among states that have standards, there are differences among states in their formulations of standards based on this perspective.

Historical Perspective

The history of technology in schools is a relatively short one, but it is characterized by drastic change across very brief epochs, as the role of technology in schools tracks the changing role of information technology in the economy and in society. This dynamic has important implications for developing technology proficiency standards, assessments, and accountability systems; policy-makers and educators should take into account that technology proficiencies may have a shorter "shelf life" than do reading or math proficiencies.

The changing conception of computer technologies as educational tools is reflected in changing frameworks for educational assessments of technology proficiency. Becker (1994, quoted in Fulton, 1997, pp.12-13) describes the history of computer technology in schools according to what teachers are told to do with technology in each phase (Figure 1).

Figure 1. Becker's (1994) Key Milestones in the History of Educational Technology

Time ↓

- Program in BASIC - the language that makes a computer work
- Program in LOGO - the program that helps student think
- Integrated drill and practice systems - individualized instruction, increasing test scores
- Word processing - computer as tools
- Curriculum-specific tools (e.g., history databases, science simulations, data probes) - integrating computers into curriculum
- Multimedia hypertext programming - curriculum change
- Internet telecommunications - connect students with world

Becker's (1994) timeline can be elaborated, drawing on Venezky (2001), among others. In the late 1970s, computers were rare in schools. A few schools experimented with LOGO, and still fewer taught programming in BASIC. In the early 1980s, the Apple II came on the scene, along with other affordable personal computers. Computer skills then become a curriculum topic, computer literacy developed as a concept at the post-secondary level in the 1980s, and computer literacy assessments were developed, although there was not much consensus on what computer literacy meant (Selwyn, 1997). Assessments developed in the 1980s focused on understanding of the computer system and the computer environment and interface, as well as applications. With the development of Macintosh and Windows operating systems, programming largely faded from standards of the typical secondary curriculum (although sometimes it was included in definitions of computer literacy in the early 1990s [e.g., Kay, 1993]).

In place of programming, appropriate and correct use of computer applications became prevalent. Then, beginning in the mid 1990s, the Internet and, even more so, the World Wide Web introduced new skills and concepts into the domain of technology proficiency. Internet research skills, information use and access, information presentation, and social and ethical issues related to technology became focal topics. In the mid 1990s, some degree of agreement on frameworks for technology proficiency emerged around these computer applications, with most assessment instruments focusing on skills and understanding involved in the use of computer applications use. However, in some cases, these frameworks are quite broad, and seem to attempt to capture all facets of technology use at the expense of being applicable to any specific domain of technology use, such as biotechnology or multimedia design.

Current Approaches to Conceptualizing Technology Proficiency

There is little consensus on conceptualizations or definitions of proficiency with educational technology, and almost no systematic empirical investigations into the domain (e.g., as a survey of workplace skills or post-secondary educational skills with technology). Definitions of educational technology proficiency underpin standards assessment frameworks, either implicitly or explicitly, and have implications for assessment design. With a couple of notable exceptions (Baker and O'Neil, 1998; Venezky, 2001), it is rare for researchers who review or put forth conceptualizations of technology proficiency to consider implications for the design of assessments in this domain.

Current conceptualizations of technology proficiency take four basic approaches: functional/applications (this encompasses the computer literacy perspective), conceptual-constructivist, electronic literacy, and the "ideological" perspective, with the last two of these defined as "alternative" approaches (cf. Fulton, 1997; Lewis & Gagel, 1992; Selwyn, 1997; Venezky, 2001). This summary leaves out some nuances within approaches, but captures the broad outlines of the conceptual domain.

Functional/Applications Approach

Most current technology proficiency assessments or frameworks are based upon an applications perspective on IT. The computer literacy perspective traditionally focused on the computer system (e.g., CPU), the computer environment (files, directories, operating systems), basic computer operation skills (mousing, keyboarding), and is frequently associated with an interest in students' attitudes toward computers. The applications perspective excludes these concerns and focuses on office applications and productivity tools and the common performance tasks with these applications. In prevalence, the applications perspective has overtaken the computer literacy approach (which some claim is entirely otiose; cf. Venezky, 2001), although the computer literacy perspective is still in use, especially by test developers (e.g., Hackbarth, 1999; Selwyn, 1997; Turner, Sweany, & Husman, 2000). The computer literacy and the applications perspectives can best be understood as near relations, both taking a functionalist approach to the domain.

The limitation of the applications perspective is, potentially, its short shelf life (Dede, 1999; Venezky, 2001). Applications face rapid obsolescence as new applications, new computer uses, and new computer types are developed. This is especially problematic for assessment, as the costs of test development prohibit frequent redevelopment.

Conceptual-Constructivist Perspective

The conceptual perspective on technology proficiency is not unrelated to the applications perspective, but it differs from the applications perspective in emphasis and in scope. One version of the conceptual approach focuses on understanding the computer and using computers on a deep conceptual level; another focuses on use of the computer *for* knowledge construction.

The version that emphasizes understanding *of* the computer emphasizes computing and information concepts. Protocols, algorithms, hardware architecture, computer languages (in general), data representation, data transmission, algorithms, operating systems, and information processing are key concepts in this perspective (Venezky, 2001). Applied to applications per se, the constructivist orientation emphasizes understanding of structures and processes over skills in use of applications (Parker, 1995).

The knowledge-construction version of the conceptual-constructivist perspective understands the computer as a tool for learning—a "mind tool", to use Jonassen's term (Jonassen, Carr & Yueh, 1998). This perspective on technology proficiency intersects with the constructivist approach to technology in learning. In the constructivist perspective, the computer is seen as a tool that supports learners' engagement in research, by assisting with investigation of complex problems that have no obvious solution, and with inquiry-based learning activities that involve data collection, analysis of data, organization information, and detection of data patterns. This perspective emphasizes use of technology-supported learning environments to scaffold students' deep learning of complex domain knowledge or higher-order thinking and problem-solving skills (Jonassen, Carr & Yueh, 1999; Parker, 1995).

Alternatives: Electronic Literacy Approach and The Ideological Approach

Third and fourth perspective are electronic literacy perspective and the ideological perspective. The electronic literacy perspective draws attention to the importance of new comprehension, production, expressive, and creative abilities that arise with the explosion of IT, and digital content (Abbott, 1994; Lewis & Gagel, 1992; Ross & Bailey, 1994; cf. Gee, 1994; and Kress & Van Leeuwen, 1996). Hypertext, Web links, nonlinear narrative and coherence relations, use of digital media, digital information manipulation and representation, design, visual literacy, and information organization are some of the skills seen as increasingly important.

This ideological approach emphasizes understanding the role and impact of the computer on society and emphasizes the new forms of literacy emerging in and necessary to learning and living in the "digital age." This perspective emphasizes that the computer is not a neutral tool, but is a social tool; that one is socialized into use of the computer for various purposes; and that computer technology has a role in society (Lewis & Gagel, 1992; Selwyn, 1997; Street, 1987; cf. Turkel, 1997). In this view, students should be taught to understand, critique, and reflect on the role of the computer. Students would be better off being prepared to critique and reflect on the role of computers in society, rather than being prepared for service demands of industry by being taught how to use computers, according to this perspective.

A Cross-Cutting Approach: Fluency

Baker and O'Neil (1998) have formulated a fairly comprehensive yet specific cognitivist conception of technology proficiency that integrates the notion of fluency. In their view fluency suggests well-developed skills, habits of mind, and understanding that results in automaticity in using technology for various purposes. Their conceptualization of technology proficiency involves three components: (1) families of cognitive demands; (2) core propensities reflecting affective and social components; and (3) focused technology skills.

Families of cognitive skills include content knowledge as well as cross-cutting, and interdependent abilities such as those related to collaboration, problem solving, self-regulation, and communication. Affective propensities include self-efficacy, effort, persistence, risk-taking, and curiosity. Focused technology skills include the kinds of skills usually addressed in the functionalist perspective described above.

The strength of this perspective is that it addresses the necessity of adaptiveness in the domain of technology proficiency. A potential limitation of it is that it is not easily formulated into an assessment framework. However, the authors do provide the broad outlines of a general approach to assessment based on this perspective that has many interesting features.

Related Domains

The above review of definitions of technology proficiency does not exhaust the broad domain of educational technology-related skills and knowledge. In addition to the above, domains such as "information literacy", "technology literacy", and "multimedia fluency" offer related though distinct conceptions of the domain and are part of the terrain of the educational technology skills and knowledge. Furthermore, career-related technology skill clusters are also used to formulated technology standards for students. Biotechnology, IT skills, multimedia design, and network administration are industry-related domains for which some secondary schools develop domain-specific technology standards for students, and for which assessments are available.

Emerging Technologies, Emerging Technology Skills

Some researchers argue that new and emerging applications of ICT in education “both require and result in new intellectual skills” (Kozma & Quellmalz, 2001, p. 5) that are brought to bear in learning problem-solving *using* ICT tools. Because technology reorganizes tasks and problems, cognition, supported by technology, is transformed and new intellectual skills arise. In this view, ICT “mind tools” (Jonassen, 1999), such as dynamic modeling tools (including spreadsheets and microworlds or simulations), support new forms of problem solving and new forms of thinking. However, these cognitive skills cannot be tapped by asking students to demonstrate their ability to use technology outside the context of problem solving in some domain. Rather, assessments are needed that require students to use ICT tools to perform complex tasks. While such complex assessments, however, are expensive and time-consuming to design, they have the potential, when well designed, to be much more revealing about what students know than selected-response paper-and-pencil tests (Pellegrino, Chudowski & Glaser, 2001).

Besides transforming cognition, technology may also transform the practices and institutions of education. Some researchers (e.g., Dede, 2001; Tinker 1999) argue that the field of education has yet to experience its “information technology revolution” the way that industry has. According to these researchers, the cumulative changes in K-12 education driven by technology, including the emergence of distance learning at the secondary level, sophistical data visualization and processing tools, and online testing, will soon issue in a profound restructuring of teaching and learning, both in terms of practices and organization. Similarly, models of technology integration in teaching and learning (e.g., Dede, 2000; ISTE, 1999; Lemke, 2001) posit a new role for the teacher, as a mentor and guide who facilitates students’ learning, and may learn along with them, rather than as an “expert” who transmits knowledge to students. This model implies that assessing teachers’ proficiency with computer applications is only an initial step in assessing their ability to use technology effectively to attain desired learning goals.

These impacts of technology, and the historical shift in conceptualizations of technology proficiency, have important implications for planning large-scale assessments of technology proficiency. The foregoing overview traces a shift in focus, from the computer per se to the use of computer applications, to the use of ICT to problem solve and learn. The notion that ICT has or will transformed the organization and processes of work and knowledge-construction and that the new skills required for (and resulting from) the technological transformation of work and learning should be assessed using ICT has profound implications for large-scale assessment of technology-related skills. This contrasts with a focus on assessment of ICT skills. The question emerges whether, as technology itself continues to change and to impact work and learning, large-scale assessments of technology proficiency may also shift focus or address both aspects of technology proficiency.

Standards for Technology Proficiency

The foregoing discussion on the various conceptualizations of technology proficiency outlines some of the challenges in formulating standards for teachers and student technology proficiency. However, technology proficiency standards are important for several reasons. Creating standards for student technology proficiency provides a community of educators an opportunity to investigate, understand, and formulate the important skills and knowledge that students need in order to be prepared for engagement in lifelong learning and work-force participation. Assuring that students have the technology-related skills and understanding necessary for current excellence and future relevance is a pressing need for educators and policy setters.

To do this, teachers must be ready to use technology and digital content in the curriculum. Whereas two decades ago computers were the target of study—with the "naming of parts" and applications, programming, and basic use the focus of study—today educators are called on to integrate increasingly diverse forms of hardware, software, and digital content into the curriculum to support powerful learning (e.g., ISTE, 2000; National Commission on Teaching & America's Future, 1996; President's Committee of Advisors on Science and Technology, 1997). Standards are needed to guide teacher training institutions and professional development programs to help prepare teachers to master information technologies and to develop the complex abilities needed to integrate these technologies into the curriculum. However, for standards to more effectively impact teaching and learning, it is necessary for standards to align with assessments, especially those used in accountability systems (Mehrens, 1998).

Overview of State and National Technology Proficiency Standards

Organizations and states creating technology proficiency standards for students must grapple with three major considerations: (1) developing or adopting an operational definition of technology proficiency; (2) defining a framework for the technology proficiency standards; and (3) articulating student and teacher competencies within the context of changing information technologies (National Research Council, 1999). A standards framework includes such dimensions as (a) whether the standards will be "stand-alone" or integrated into the core subject areas; (b) whether the standards will be "one size fits all" or whether a range of standards will be available for different grade ranges or different career trajectories or concentrations; (c) the scope and depth of skills and knowledge addressed in the standards; and (d) the grade ranges for which skill standards (proficiency levels and developmental levels) will be differentiated. Each of these aspects has important implications for assessment design, implementation and accountability systems, and the pattern of directions that different states take have implications for the opportunities and challenges that policy-makers and researchers will face in aggregating attainment data across states.

For this review study, we conducted a comparative analysis of a diverse set of student, teacher, and administrator standards. Table 7 shows the standards that were reviewed. The reviewed standards do not constitute an exhaustive inventory of national or state standards but are rather a purposive (though not systematic) sample intended to represent the range of standards that are illustrative of key issues in the development of technology proficiency standards. Three key dimensions along which student technology standards differ are (1) the content focus, (2) whether they are "stand alone" or integrated, and (3) whether standards took into account technology change.

Table 7. Technology Proficiency Standards Review for Comparative Analysis

	Student Standards	Teacher Standards	Administrator Standards
AASL & AECT's Nine Information Literacy Standards for Student Learning (2000)	X		
Coughlin & Lemke (1999)		X	X
Idaho Mathematics and Science Standards (2000)	X		
Illinois Technology Standards in English Language Arts (1997)	X		
International Technology Education Association Standards (2001)	X		
ISTE-NETS (2000)	X	X	X
Johnson & Bartleson (1999)			X
Michigan Technology Content Standards (1998)	X		
National Research Council's FITness Standards (1999)	X		
National Technology Leadership Initiative papers (2000)	X		
North Carolina Computer/ Technology Skills Curriculum (1998)	X		

Content Focus of Student Technology Proficiency Standards

Skills vs. Intellectual Capabilities

The National Research Council (1999) and International Society for Technology in Education's (ISTE) National Education Technology Standards for students (2000a-e) are the two major national technology proficiency standards and have influenced state and district standards formulations. The former standards take a more abstract approach to technology proficiency, organized around the notion of "fluency", while the latter take a more skills-oriented approach, although skills are described at a fairly general level, rather than being operationalized in terms of concrete classroom tasks or activities.

In the National Research Council's technology proficiency standards the term *fluency* signals a level of mastery such that individuals "understand information technology broadly enough to be able to apply it productively at work and in their everyday lives, to recognize when information technology would assist or impede the achievement of a goal, and to continually adapt to the changes in and advancement of information technology" (NRC, 1999, p. 15). In these standards, technology proficiency is seen as an independent set of concepts, skills, and capabilities, a distinct field involving certain intellectual capabilities and concepts, and skills related to information technology. Exhibit 1 presents a list of ten major elements presented for each level of what the National Research Council terms "FITness."

Exhibit 1. Elements of Technology Fluency (FITness)

Intellectual Capabilities	**Information Technology Concepts**	**Information Technology Skills**
Engage in sustained reasoning Manage complexity Test a solution Manage problems in faulty solutions Organize and navigate information structures and evaluate information Collaborate Communicate to other audiences Expect the unexpected Anticipate changing technologies Think about information technology abstractly	Computers Information systems Networks Digital representation of information Information organization Modeling and abstraction Algorithmic thinking and processing Universality Limitations of information technology Societal impact of information and information technology	Setting up a personal computer Using basic operating system features Using a word processor to create a text document Using a graphics and/or artwork package to create illustrations, slides, or other image-based expressions of ideas Connecting a computer to a network Using the Internet to find information and resources Using a computer to communicate with others Using a spreadsheet to model simple processes or financial tables Using a database system to set up and access useful information Using instructional materials to learn how to use new applications or features

Source: National Research Council, 1999.

In contrast to this abstract notion of technology proficiency, the ISTE-NETS standards conception of technology proficiency is highly skills-oriented. This conception of technology proficiency usually emphasizes the ability to use standard computer applications such as spreadsheets and databases. Skill standards based on this computer skills-oriented notion of technology proficiency usually set forth proficiencies in common computer software tools such as word processing, email, Internet navigation and research, spreadsheets, presentation software, and course-specific software (ISTE, 2000).

The International Society for Technology in Education (ISTE) technology foundation standards for students emphasize not only the importance of knowing how to use technology systems but also how to use systems for other tasks. Embedded in the ISTE standards is a strong belief that technology is first and foremost a *tool* for learning (see Exhibit 2).

Exhibit 2. ISTE-NETS Technology Foundation Standards for Students

1. Basic operations and concepts
Students demonstrate a sound understanding of the nature and operation of technology systems.
Students are proficient in the use of technology.

2. Social, ethical, and human issues
Students understand the ethical, cultural, and societal issues related to technology.
Students practice responsible use of technology systems, information, and software.
Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity.

3. Technology productivity tools
Students use technology tools to enhance learning, increase productivity, and promote creativity.
Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works.

4. Technology communications tools
Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences.
Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences.

5. Technology research tools
Students use technology to locate, evaluate, and collect information from a variety of sources.
Students use technology tools to process data and report results.
Students evaluate and select new information resources and technological innovations based on the appropriateness for specific tasks.

6. Technology problem-solving and decision-making tools
Students use technology resources for solving problems and making informed decisions.
Students employ technology in the development of strategies for solving problems in the real world.

Source: ISTE/NETS (http://cnets.iste.org/index2.html).

Like the National Research Council's FITness standards, the ISTE-NETS standards treat technology proficiency as an independent domain with its own set of standards. The ISTE-NETS technology proficiency standards do include some references to subject area applications, but they are presented as performance profiles or examples of standards, rather than being integrated into the standards themselves. But the ISTE-NETS standards also make some explicit assumptions about how students will encounter and master new technologies in their K-12 experiences, which the FITness standards do not address in great detail, focusing more on implications for implementing the standards at colleges and universities (NRC, 1999). The ISTE standards assume that students will encounter technology throughout the curriculum through a set of “coordinated activities” (ISTE, 2000). These standards reflect a belief that “all students should have the opportunity to develop technology skills that support learning, personal productivity, decision making, and daily life” (ISTE, 2000). The ISTE standards have been adopted by several states—Arizona, Oklahoma, and Utah, for example—as the basis for their own technology proficiency standards.

Focus on Software Applications

Working definitions of technology proficiency that guide most of the standards conceptualize technology as a tool applied to other skill areas and to problem solving. Even standards documents that emphasize technology proficiency as an independent domain, such as those developed by ISTE, for the most part emphasize technology’s role in supporting problem solving. This emphasis on *software applications technology as learning tools* is seen across most standards even when other dimensions of scope vary in fundamental ways. For example, the FITness standards (National Research Council, 1999) expresses most of the 10 priority information skills in terms of software applications, such as “using a word processor to create a text document” and “using a computer to communicate with others” (National Research Council, 1999). In the ISTE student standards, only one of the six categories of standards defines technology proficiency independent of use to support problem solving: “Basic Operations and Concepts.” The rest define technology proficiency by the uses of technology: “Productivity Tools,” “Research Tools,” “Communications Tools,” and “Problem-solving and Decision-making Tools” (ISTE, 2000). A sixth category, “Social, Ethical and Human Uses”, is focused on understanding how technology is used as a tool in the broader society. The ISTE-NETS standards are dominated by specific technology skills, such as discrete applied tasks (ISTE, 2000a). Only two of ISTE’s 14 foundation standards require students to “understand” concepts, and only one mentions specific habits of mind (“positive attitudes toward technology uses”) (ISTE, 2000a).

Technology Applied in Industry

Application of technology in industry is heavily emphasized when technology standards focus on areas of career specialization. For example, the ITEA’s Technology for All Americans project (ITEA, 2000) includes standards and benchmarks specific to particular professional applications of technology: (1) Medicine; (2) Agriculture and related biotechnologies; (3) Energy and power technologies; (4) Information and communication; (5) Transportation; (6) Manufacturing; and (7) Construction

Similarly, in its publications on technology proficiency the CEO Forum recommends a greater emphasis on skills required for professional tasks that are not currently common in the classroom. “Business leaders should work with educational and federal and state government organizations to define the evolving criteria of 21st century skills” (CEO Forum, 2001, p. 20). These skills include proficiency in uses of technology that are specific to an office workplace, such as scheduling and online meeting tools (CEO Forum, 1999). This implies that both students and teachers need to expand their uses of technology to keep up with skills required in the workplace.

Pennsylvania’s student technology standards emphasize the importance of preparing students to use technology as professional scientists do. Much like other state standards, the Pennsylvania standards include generally applicable skills such as “problem solving in technology,” “technological devices,” and “science, technology and human endeavors” (Pennsylvania Department of Education, 2001). However, they also include specific professional applications. Similarly to the ITEA standards, a separate standard category, Technology Education, lists biotechnology, information technology, and physical technologies (construction, manufacturing, and transportation) as important domains of technology proficiency for students (Pennsylvania Department of Education, 2001).

Independent vs. Integrated Student Technology Proficiency Standards

A key dimension of variation among technology proficiency standards is whether technology-related competencies are integrated with core subject area standards or whether they are “stand-alone” standards. Most standards we reviewed address technology proficiency as a distinct subject area.

Because many states with independent technology proficiency standards adopted the ISTE standards, we take the ISTE to be representative of independent technology standards.

One national effort that reflects the desire to integrate or embed technology proficiency standards within core subject areas was undertaken by the National Technology Leadership Initiative. The National Technology Leadership Initiative has separately published guidelines for science and mathematics that recommend the inclusion of core subject-specific technology competencies into standards (Flick & Bell, 2000; Garofalo *et al.*, 2000). These include skills such as modeling atmospheric phenomena using science-specific software and using computer-based data probes to collect real-time data from laboratory experiments (Flick & Bell, 2000). Because these recommendations include technology uses specific to math and science that are not present in other subject areas, they include technology skills and concepts that are omitted from cross-disciplinary standards.

When technology proficiency standards are integrated into subject-area standards, a range of strategies are used to organize this integration. One strategy is to group technology-related skills and knowledge together with science. Pennsylvania (2001), for example, has developed linked science and technology standards, presented below in Exhibit 3. The science and technology standards contain eight standard categories, which among them cover three content areas: science, technology education, and technology tools.

Exhibit 3. Pennsylvania Academic Standards for Science and Technology

	Content Areas		
Standard Category	**Science**	**Technology Education**	**Technological Tools**
1. Unifying Themes	X	X	X
2. Inquiry and Design	X	X	X
3. Biological Sciences	X		
4. Physical Science, Chemistry and Physics	X		
5. Earth Sciences	X		
6. Technology Education		X	
7. Technological Devices			X
8. Science, Technology and Human Endeavors	X	X	X

Source: Pennsylvania Department of Education, 2001

Some states incorporate technology standards into some subjects but not others. For example, in California, student technology proficiency standards are incorporated in content standards for Language Arts and History-Social Science. The technology proficiency-related standards in these areas focus on information literacy rather than educational technology skills and knowledge. Neither Math nor Science standards systematically incorporate technology-related standards.

Illinois takes a different approach from Pennsylvania, identifying technology as a cross-discipline theme, not a distinct content area (Illinois State Department of Education, 1997). Technology proficiency standards are distributed throughout the core academic standard categories. For example, the technology standards in English Language Arts emphasize visual and media literacy and the frequent use of word processing and online services in communication and research (Exhibit 4). This approach promotes “learning with” technology, rather than “learning about” technology (Fulton, 1997).

Exhibit 4. Illinois’s English Language Arts Goal 3: Write to Communicate For a Variety of Purposes

English Language Arts Goal 3: Write to communicate for a variety of purposes.
Learning Standard 3.C. Communicate ideas in writing to accomplish a variety of purposes.
Benchmark 3.C.4b [Early High School] Using available technology, produce compositions and multimedia works for specified audiences.

Source: Illinois State Department of Education, 1997

In some cases, states have adopted a hybrid approach to their technology proficiency standards, incorporating the view of technology proficiency as a distinct skill domain and also as skills embedded within the curriculum. In Virginia, for example, technology proficiency standards are incorporated throughout the learning standards in the core academic subject areas (Virginia Board of Education, 1995-2001). But there are also stand-alone technology standards for students in grades 5, 8, and 12. Similarly, Michigan’s standards include benchmarks for using instructional technology across the curriculum, both in core academic areas as well as the arts, music, physical education, special education, and media centers (Michigan Department of Education, 1998). At the same time, the standards also emphasize stand-alone technology skills like keyboarding and basic programming skills. North Carolina has an independent Computer/Technology Skills Curriculum(North Carolina Department of Public Instruction, 1998), in which specific competency goals are emphasized across the primary and secondary levels. Three competency goals organize the grades K-12 technology curriculum (Exhibit 5). For grades K-8, the computer/ technology skills standards make no reference to individual subject areas. However, in grades 9-12, four or five individual standards are presented for eight different core subject areas and embed technology skills deeply with specific subject matter. Exhibit 6 presents the standards for technology use within Foreign Languages in North Carolina as an example.

Exhibit 5. North Carolina Computer/Technology Skills Curriculum

Competency Goal 1: The learner will understand important issues of a technology-based society and will exhibit ethical behavior in the use of computer and other technologies.
Competency Goal 2: The learner will demonstrate knowledge and skills in the use of computer and other technologies.
Competency Goal 3: The learner will use a variety of technologies to access, analyze, interpret, synthesize, apply, and communicate information

Source: North Carolina Department of Public Instruction, 1998.

Exhibit 6. Foreign Languages Standards, North Carolina Computer/Technology Skills Curriculum

3.1 Select and use appropriate technologies to communicate in other languages with other cultures.
3.2 Select and use technological tools for class assignments, projects, and presentations.
3.3 Adhere to Fair Use and Multimedia Copyright Guidelines, citing sources of copyrighted materials in papers, projects, and multimedia presentations.

Source: North Carolina Department of Public Instruction, 1998.

The decision whether to view technology proficiency as an independent domain or to embed proficiency standards within specific subject areas has implications for the range and scope of standards. On the one hand, assigning technology proficiency its own domain potentially expands the possible range of topics to be covered by the standards. On the other hand, concontextualization from disciplinary topics of study might make the standards seem more abstract to educators. Subject-matter embedded standards, by contrast, offer more detail about applications of technology, but they may not include the range of proficiencies encompassed in most definitions of technology proficiency because these fall outside any particular disciplines domain.

How Adaptable are the Standards to Changing Technology?

Standards pay differential attention to the issue of technological change. Some standards like those developed by the National Research Council (1999), tackle the issue head-on in their discussion of the skills, capabilities, and concepts that comprise their definition of fluency with information technology. For example, the FITness standards include as an “intellectual capability” the ability to “anticipate changing technologies” (National Research Council, 1999, p. 4). ISTE student standards include the ability to identify new technologies: “Students evaluate and select new information resources and technological innovations based on the appropriateness for specific tasks” (ISTE, 2000b).   Moreover, students in the ISTE standards are expected to be able to “demonstrate knowledge of current changes in information technologies and the effect those changes have on the workplace and society” (ISTE, 2000, Grades 5-8 standards).

The National Research Council’s FITness framework (1999) also addresses the issue of adaptability in its delineation of different rates of change for skills, information technology concepts, and intellectual capabilities. Skills are seen as recognized as changing relatively rapidly, concepts more slowly, and intellectual capabilities the most slowly in the face of larger changes in information technologies. In order to be consistent with the overall thrust of the approach, the National Research Council recommends that the list of information technology skills be regularly reviewed and revised whenever this framework is adapted for state or district standards.

At the same time, neither the FITness nor the ISTE standards specify how students acquire the skills to master new technologies. Similarly, state standards may acknowledge that technologies are constantly changing, but they typically do not specifically incorporate notions of rates of change or anticipate new technologies in their standards. Some state and national standards do emphasize one aspect that relates to technological change, namely the role of technology in society. The social and ethical implications of technology are the most popular additions to national standards such as ISTE and to most state standards. These standards require individuals to use technology for responsible purposes, adhere to copyright laws, respect other individuals, empower learners, and ensure equitable access to technology, among others (ISTE, 2000c; ALA & AECT, 1998).

Summary and Conclusions

There is wide variation in the definition and scope of technology proficiency, as well as in approaches to standards in this domain. Technology proficiency may be subsumed altogether under a larger umbrella concept that is taken as underlying a meaningful definition of technology proficiency. Teacher and administrator standards not only emphasize skill in the application of technology to support curriculum development, instruction, and assessment, but also skill in using technology to support professional productivity and communication.

As states attempt to implement standards that emphasize both technology proficiency as a stand-alone set of skills and as skills integrated throughout the curriculum, they are likely to come up against a problem Kay (1993) identified. The uses of technology will continue to diversify and proliferate at an extremely rapid rate. Kay (1993) argues that it is unrealistic and inefficient to expect all secondary students to have a complete range of computer-related skills. This author recommends that technology proficiency standards creation and assessment development should be driven by a "personal needs" approach. This view implies that, rather than developing one-size-fits-all standards and all-inclusive measures of technology proficiency, multiple types of standards and suites of assessments should be developed that take into account the many, and continuously proliferating, roles of technology in the economy and in society.

Assessing Educational Technology Proficiency

Technology proficiency standards for teachers and students are increasingly available at the national, state, and district levels. However, to understand and track progress against these standards as well as to verify that teachers and students are gaining the technology proficiencies that are increasingly necessary in teaching and learning, work, and private life, assessment and accountability programs are necessary. In addition, assessments coupled with accountability systems— if designed and used appropriately— motivate teachers and students to acquire the knowledge and skills identified in the standards (e.g., Darling-Hammond & Falk., 1997; Linn, 2000). Moreover, for educational accountability purposes, outcome data based on direct assessments are more appropriate than input indicators such as the number of computers in a particular school or course units (American Educational Research Association/American Psychological Association/National Council on Measurement in Education [AERA/APA/NCME], 1999).

Our review found that at present, few instruments are available for assessment of technology proficiency of K-12 students and teachers, and fewer still are suitable for use in high-stakes decisions, when evaluated against professional standards for high-stakes testing (AERA/APA/NCME, 1999; Chronbach, 1990). Given that technology proficiency standards are relatively new, beginning to appear only within the last several years, this is not surprising. However, the need for high-quality technology proficiency assessments is growing as more states and districts develop technology proficiency standards, as technology becomes increasingly used in and necessary to instruction, as outcome data bearing on the effects of educational technology use are more in demand by educators and policy makers, and as technology in the economy becomes ever more pervasive. However, because the majority of states that have technology proficiency standards (31 states) have standards that are integrated with subject area standards (21 states) rather than stand-alone technology standards (9 states), the development of standards may not be a strong driver for the need for technology proficiency assessments. States that have integrated technology standards will not be as likely to opt for independent tests of technology proficiency.

Key Issues in Large-Scale Assessment and Accountability

Technical Qualities of Assessment Instruments

Educational assessment is "the process of drawing reasonable inferences about what students know on the basis of evidence derived from observations of what they say, do, or make in selected situations" (Pellegrino, Chudowsky, & Glaser, 2001, p. 105). Understanding of the fundamentals of test development and interpretation is critical in large-scale assessment in any domain, but is perhaps especially important in the domain of educational technology proficiency because the technical qualities of most (but not all) currently available direct measures are poor or unknown. It is important for policy-makers and educators to understand the limitations of current instruments and the implications for accountability and the interpretation collected with such instruments (see Exhibit 7).

To yield sound data regarding students' and educators' technology proficiency, development and implementation of technology proficiency tests for large-scale assessment should be aligned with the standards and principles set forth in the *The Standards For Educational And Psychological Testing* (AERA/APA/NCME, 1999 [also referred to as *The Standards*]; see also Cronbach, 1990). The standards of validation for educational tests apply uniformly to all assessments types, including multiple-choice tests, performance assessments, and portfolio assessments.

Exhibit 7. Technical Qualities of Instruments: Some definitions

Validity: "[A]n overall evaluative judgment of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of interpretations and actions based on test scores." ((Messick, 1995, p. 5) (However, common usage refers to the validity and reliability *of* tests)

Test Validation: Test validation is process intended to minimize error in measurement, which cannot be totally eliminated (Brennan, 1998). Validation of a test is an inquiry process that involves accumulating two types of evidence: evidence bearing on validity and evidence bearing on reliability (Chronbach, 1990). Each kind of evidence can be gained using a variety different methods. Validity is generally seen as having three related aspects, construct validity, content validity, and criterion validity (Chronbach, 1990).

Construct validity: This has to do with how well the test "gets at" the domain for which it is supposed measure ability/aptitude. Defining test constructs involves a theory or a set of related assumptions about the processes or factors (e.g., differences among individuals) that account for the varying responses of individuals on the measures (e.g., why do some people score high and others low?). Types of evidence bearing on construct validity include internal consistency, correlation with practical criteria, demographic correlates, content analysis, relationship to subjects' experience, experiment with varied testing conditions.

Content validity: This involves the degree to which, and adequacy with which, the target domain is represented on the test, in terms of both the extent to which the domain is covered and how the target domain is presented (e.g., item format).

Criterion validity: This is also referred to as predictive validity, and pertains to the predictive validity of a test, for example, how well a score on the test under study predicts a score on another, established measure, or how well the score relates to evidence of ability or performance level gained in another context or on an alternative (often more elaborate) assessment.

Reliability: This has to do with the consistency or inconsistency in examinees' scores (Brennan, 1998). In test validation, gaining reliability evidence can involve a variety of procedures, including retesting individuals on an instrument, and having multiple scorers score the same performance or product.

(Based on Chronbach [1990] and AERA/APA/NCME [1999], among others.)

Technology proficiency poses several test validity issues that should be considered in instrument development and use related to this domain. For example, in relation to construct validity, a performance assessment designed to test word processing skills that is computer-based may be said to have greater construct validity than a paper-and-pencil test. However, a computer-based word processing task must use a specific word processing application. Imagine a job applicant who is expert in using Microsoft Word for word processing being given a word processing test in WordPerfect. He would probably not pass the test. Knowledge pertaining to the operation of a specific word processing application is "construct-irrelevant" to the assessment of word processing skills per se. This implies that tasks must be designed carefully to assess skills at a level of generality so that target skills (e.g., word processing) are assessed in a “vendor neutral” context. This issue is relevant to all computer-based administrations of assessments of skill with computer application. Mode of administration may also be considered as a source of construct-irrelevant differences in test scores. A study of composition assessment in Massachusetts found that mode of administration had a significant impact on student performance. Students who primarily composed on the computer for classroom writing assignments performed significantly better when they composed essays on computer than when they used paper and pencil (Russell& Plati, 2000). The effect was about the same in grades 4, 8 and 10.

Another aspect of construct validity that may be important to consider for technology proficiency assessment concerns the “reach” of the construct “technology proficiency” (or cognates such as “computer literacy” or entailed competencies such as “proficiency with office productivity tools”). Because the domain of technology proficiency is relatively ill-defined, as compared to reading comprehension, it is important that test constructs be clearly validated, and that test users understand and evaluate the relevance of the test construct for the test purposes.

Often the construct “technology proficiency” encompasses the ability to use technology to solve problems or perform complex tasks, such as organizing or evaluating information, or making inferences from data. For example, the ISTE-NETS standard describes competence with “technology productivity tools” as involving the following: “Students use technology tools to enhance learning, increase productivity, and promote creativity. Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works” (ISTE, 2000a). While this is not an operationalized definition suitable for an assessment framework, it does indicate that an assessment of technology proficiency aligned with this standard ought to assess students’ achievement in “learning with” technology rather than in “learning about” technology (Fulton, 1997). However, most technology proficiency assessments for students test students’ ability to operate computer applications rather than their ability to “learn with” computer applications or use them to solve complex problems.

This aspect of construct validity in technology proficiency assessment has important implications for accountability programs. According to data from the ISETS study, currently nine states have adopted ISTE-NETS or standards from other organizations (see below). States that have adopted or intend to adopted technology proficiency assessments should be aware of the construct the test is designed to assess and should, if the test is to be part of an accountability system, evaluate the alignment of the test with state technology standards. The *Standards* states that test developers have an obligation to clearly describe the construct a test is designed to assess (AERA/APA/NCME, 1999, Standard 1.2).

Standards for Test Development and Use

For instruments used in large-scale, high-stakes testing, full instrument validation is necessary, which includes collecting data pertaining to the validity and reliability of specific instruments for specific uses (in addition to other dimensions of test use, such opportunity to learn and consequential validity) (AERA/APA/NCME, 1999). In addition, administration of tests and uses of data should follow the guidelines set for the *Standards*, which represents the consensus of the field regarding appropriate test use in education. Based on the *Standards*, The American Educational Research Association's Position Statement Concerning High-Stakes Testing in PreK-12 Education (AERA, 2000) highlights the "essential conditions" of test use in schools, and is excerpted in Exhibit 8.

In connection to the assessment of technology proficiency, several of these "essential conditions" are most relevant to consider, particularly opportunity to learn, and issues pertaining to the consequences of testing.

Exhibit 8. AERA Position Statement Concerning High-Stakes Testing in PreK-12 Education (Excerpts)

This statement sets forth a set of conditions essential to sound implementation of high-stakes educational testing programs. It is the position of the AERA that every high-stakes achievement testing program in education should meet all of the following conditions:

Adequate Resources and Opportunity to Learn
[…] [I]t must be shown that the tested content has been incorporated into the curriculum, materials, and instruction students are provided before high-stakes consequences are imposed for failing examination.

Full Disclosure of Likely Negative Consequences of High-Stakes Testing Programs
Where credible scientific evidence suggests that a given type of testing program is likely to have negative side effects, test developers and users should make a serious effort to explain these possible effects to policy makers.

Ongoing Evaluation of Intended and Unintended Effects of High-Stakes Testing
With any high-stakes testing program, ongoing evaluation of both intended and unintended consequences is essential. In most cases, the governmental body that mandates the test should also provide resources for a continuing program of research and for dissemination of research findings concerning both the positive and the negative effects of the testing program.

Alignment Between the Test and the Curriculum
Both the content of the test and the cognitive processes engaged in taking the test should adequately represent the curriculum. High-stakes tests should not be limited to that portion of the relevant curriculum that is easiest to measure. When testing is for school accountability or to influence the curriculum, the test should be aligned with the curriculum as set forth in standards documents representing intended goals of instruction. […]

Appropriate Attention to Language Differences Among Examinees
If a student lacks mastery of the language in which a test is given, then that test becomes, in part, a test of language proficiency. Unless a primary purpose of a test is to evaluate language proficiency, it should not be used with students who cannot understand the instructions or the language of the test itself. If English language learners are tested in English, their performance should be interpreted in the light of their language proficiency. Special accommodations for English language learners may be necessary to obtain valid scores.

Source: AERA, 2000.

Opportunity to Learn

Opportunity to learn is an issue critical to sound assessment of technology proficiency. Research indicates that students who have greater access to computers outside of school perform better on tests of technology proficiency (Pelgrum, Janssen & Plomp, 1993; Sanford, 2000), although this finding may depend on how much instruction in technology students receive in school. This has important implications the incorporation of technology proficiency into testing programs as students substantially differ in their access to and use of computers (PCAST, 1997), both in school and outside of school. A 2000 study by the U.S. Department of Commerce, for example, found an 18 percentage-point difference in Internet access between Black and White households. Thus, as assessment of technology proficiency increases, it will be important educators to evaluate the opportunity to learn in association with the instruments (AERA/APA, NCME, 1999, p. 146). In addition, to create tests that are suitable for educational accountability, test developers must verify that instruments are sensitive to instruction and are not in fact measuring differences in access to computers outside of school.

Consequential Validity

Consequential validity has to do with the uses of tests and the consequences of testing. Evidence pertaining to consequential validity bears on the positive and negative outcomes associated with use of the test. While measurement experts debate whether obtaining evidence related to consequential validity should be part of test development (e.g., Linn, 1997; Messick, 1989) or whether this is the onus of test users (e.g., Popham, 1997), the principle that examination of the appropriateness, adequacy, and fairness of a specific test for specific purposes is an important aspect of assessment and accountability is not debated (Shepard, 1997). The *Standards* states that test users are obligated to provide evidence of indirect benefits of tests or test programs (such as improvements in teaching practices), when indirect benefits are claimed, and that when negative consequences of testing or test programs are observed, users must investigate whether the consequences are attributable to a test's sensitive to characteristics other than those it is intended to assess (AERA/APA/NCME, 1999, Standards 1.23, and 1.24).

In planning statewide assessment and accountability programs, both the intended consequences of testing as well as the unintended consequences of the testing should be examined (Lane, Parke, & Stone, 1998). For statewide assessments, intended consequences may include improvement in learning for all students, the nature of professional development, student and educator motivation, and instructional strategies and content. Unintended consequences may include narrowing of curricula, orientation to superficial aspects of the construct addressed in assessments, rather than its more complex aspects, and unfair or unethical uses of test scores (Lane, Parke, & Stone, 1998). Evaluation of the consequences of an assessment program could involve surveying students, teachers, and administrators, conducting focus group interviews, and classroom observation.

With respect to the assessment of technology proficiency, two types of negative consequence could be of particular concern. The first is the narrowing of instruction to focus on the superficial or specific aspects of the construct, technology proficiency, at the expense of the broader, more complex aspect of the construct. While the definition of technology proficiency has not been consensually established (see below), in state and national standards, it is usually described as encompassing a broad range of skills, habits of mind or attitudes, and concepts; however, only a narrow range of these is represented in most assessments of technology. This inattention of the more complex, intellectual aspects of technology proficiency, the aspects of technology proficiency that involve facility with learning new technologies, could result in students' not be adequately prepared for lifelong learning and adaptation to new technologies.

Overview of Technology Proficiency Assessment Instruments and Their Uses

For the review of summarized here, direct measures (as opposed to self-report questionnaires) of technology proficiency were collected from states, organizations, private firms, and researchers as part of an extensive instrument collection process conducted from October 2000 through July 2001. We targeted direct measures designed to assess proficiency with educational technology, as opposed to specialized technical skills such as network administration. Extensive efforts were made to obtain any scoring manuals, technical reports, and validity evidence associated with each instrument. (Note that detailed information regarding each assessment instrument discussed here is contained in the Student Instrument Matrix, Post-secondary student/adult Instrument Matrix and Teacher Instrument Matrix, Appendices A, B and C.) All collected instruments and associated documents were carefully reviewed, based on Chronbach's (1990) test evaluation criteria, to evaluate technical quality and framework.

Our review study identified 49 technology proficiency assessment instruments. Of these, 23 instruments are for students, 18 instruments are for teachers, and seven are for post-secondary students and adults. Only a handful of these instruments are, however, used for large-scale assessment. In North Carolina, passing the North Carolina Tests of Computer Skills is a high school graduation requirement for all students, while the Virginia SOL Computer/Technology Assessment is used for school and state accountability purposes. We found that Idaho and North Carolina make technology proficiency assessment a prerequisite for initial teacher licensure. This indicates that large-scale technology proficiency assessment is still in its very early stages.

Our review revealed that few instruments appear to meet the standards for educational assessment (AERA/APA/NCME, 1999). Clear exceptions are the student assessment instruments used in North Carolina and Virginia. The technical reports of these instruments provide reasonably comprehensive information about the development and validation process. We also obtained several other instruments with less adequate reporting of technical quality information, most of which are multiple-choice tests. Note that for some instruments for which we could not obtain technical reports or other supporting documentation, we were not able to determine that such were not available, although a concerted effort was made to do so. Very little validity evidence was available for performance assessments and portfolios. Detailed information was seldom reported on how scoring is done (e.g., scoring rubrics) or on its reliability (e.g., inter-rater reliability).

Student Assessment Instruments

Instruments Used in Large-Scale Assessment

Among then 49 technology proficiency assessment instruments we identified through our search, 23 instruments are designed for K-12 students (the instruments reviewed in this section are presented in Table 8). Of these, few instruments are currently in use in statewide testing of the general technology competencies of K-12 students for high-stakes decisions. We identified instruments in use in North Carolina and Virginia. No other technology proficiency assessment instruments were identified that sample a broad range of technology proficiencies (such as those set forth in the ISTE NETS standards) and that are suitable for use in large-scale assessment programs with high-stakes decisions attached to them. The Virginia SOL Computer/ Technology Tests (consisting of the 5th grade and 8th grade tests) are not used for high-stakes decisions about individual students but rather are part of the statewide school accountability program. In North Carolina, on the other hand, technology proficiency assessment is a high school graduation requirement for all students. In addition, in Kansas, a technology proficiency assessment instrument is also used for admissions to state colleges.

Table 8. Student Technology Proficiency Instruments Reviewed

Purposes		Example Instruments
Large-Scale Assessment	**High school graduation requirement**	North Carolina Tests of Computer Skills Multiple-Choice Test Performance Test
	College admission	Kansas Technology Proficiency Examination (Fort Hays State University) Kansas Technology Proficiency Examination (University of Kansas)
	Local purposes	Idaho Student Technology Assessment Grade 3-5 Test Grade 6-8 Test Grade 9-12 Test
	School accountability	Virginia SOL Computer/Technology Tests 5th Grade Test 8th Grade Test
	Certification/qualification	California Assessments in Career Education Technology Core Computer Science & Information; UK Key Skills Qualification Information Technology Assessments Level 1 External & Internal Assessments Level 4 External & Internal Assessments Level 3 External & Internal Assessments Level 4 External & Internal Assessments
Small-Scale Assessment	**State accountability programs** **Research evaluation**	The IEA Functional Information Technology Test (FITT) OECD/CERI ICT Program's Skills and Concept Test and Information Handling Test
	Aid for learning, classroom use	Aries Computer Literacy Exams Alberta Classroom Assessment Kit

Several instruments are available for technology proficiency assessment in business, career, and vocational education programs. These instruments focus more narrowly on technology competencies relevant to office work, or on more specialized technology proficiencies, such as data processing and network administration. For example, California's Assessments in Career Education (ACE) program (which comprises the Technology Core test and Computer Science & Information Systems test) and the United Kingdom's Key Skills Qualification program (which encompasses four levels of assessment) are voluntary tests offered to secondary students enrolled in career-technical courses. Students who successfully complete these assessments are awarded formal recognition (in California's program) or a qualification in information technology (IT) (in the UK's program).

North Carolina's Tests of Computer Skills are the only instruments used as a high school graduation requirement and administered to all students and consist of a Multiple-Choice Test (paper-and-pencil) and a Performance Test (computer based) (North Carolina Department of Public Instruction, 2001). The first opportunity for students to take these tests is in the 8th grade. A student who fails a test at the first trial can retake the test multiple times per year throughout high school. As the title suggests, North Carolina's tests focus on computer skills, especially on the basic operations of software applications such as word processing, databases, spreadsheets, multimedia presentations, and telecommunications. (The technical qualities, content, format, and assessment framework of these tests are discussed below.)

In Kansas, several instruments are in use as part of the state college admission requirement. The University of Kansas and Fort Hays State University independently developed the Computer Technology Proficiency Examinations for college-bound students. The instrument developed by the University of Kansas is computer based, while the test developed by Fort Hays State University is paper-and-pencil. These tests can be taken to fulfill the college admission requirement of the Kansas Board of Regents. To qualify as an instrument for state college admission, the instrument must cover four areas, as identified by the Kansas Board of Regents: (1) Operating Systems and Hardware, (2) Computer Software, (3) Networking and the Internet, and (4) Social and Ethical Issues in Computing (Kansas Board of Regents, n.d.). (The technical qualities, content, format, and assessment frameworks of these are discussed below).

In Virginia, technology proficiency assessment is conducted as part of Virginia Standards of Learning (SOL) Assessments, a statewide standardized testing program. The Virginia SOL Computer/Technology Tests are administered to 5th grade students and to 8th grade students typically in the end of an academic year. Both the 5th grade and 8th grade tests are paper-and-pencil, each containing 50 multiple-choice questions (Virginia State Department of Education, 1997a, 1997b). Students are assessed on their basic knowledge about the operation of application software as well as on their information literacy. Although no high-stakes decisions are made based on the test results, two cutoff scores are established to identify three levels of achievement for accountability purposes: does not meet the standards (fail), proficient attainment of the standards (pass), and advanced attainment of the standards (pass). The advanced passing rate is 90% in both tests, while the proficient cutoff score for the 5th grade test is 57% and for 8th grade test is 65% (Virginia State Department of Education, 2000a). The Virginia State Department of Education reports the percentage of students passing rate (proficient and advanced level combined) for individual schools on its website (http://www.pen.k12.va.us/VDOE/Assessment/soltests/y2kscores.html).

Instruments Used in Small-Scale Assessment

We identified a variety of instruments that are suitable for use in small-scale/low-stakes assessment contexts. (Note that the main target of our instrument collection process were instruments suitable for use in large-scale assessment.) These instruments in general are used on a small scale for research purposes (including program evaluation) or as aids for learning in classrooms.

Web-based technology proficiency assessments for the three grade ranges 3-5, 6-8, and 9-12 have been developed by Boise State University. These assessments were developed as part of the University's educational technology outreach program and are designed for district- or school-level use as pre- and post-tests, or as placement tests. The Idaho State Department of Education does not plan to adopt these tests for statewide assessment (C. Thorsen, personal communication, May 15, 2001).

Several assessments are available for use in classroom instruction. We found one instrument and one assessment tool kit that are designed for use as formative assessments and that allow teachers to adjust the content of assessments to their classroom contexts. For example, the Aries Computer Literacy Exams are online tests built into the Aries Computer Literacy Curriculum (Aries Technology, n.d.). The Curriculum, which is available both in a CD-ROM format and in a website format, includes four types of exams: pre-tests, post-tests, final tests, and unit tests.

Instruments designed for research purposes were developed for several attainment studies within the U.S. and abroad. These studies include the National Assessment of Educational Progress (NAEP) Computer Competence Assessment Study (1985-86), the IEA study on Computers in Education Study Stage 2 (1992), the Finland ICT assessment study (1997-98), and the OECD/CERI study on the Impact of Student Learning (2000). These instruments are usually used in association with attitude questionnaires. Each of these instruments is discussed below. (The NAEP and Finland ICT instruments were not among instruments extensively reviewed for this study.)

The NAEP Computer Competence Assessment is a paper-and-pencil, direct measurement designed to assess the computer competency. The majority of the items are multiple-choice questions, although the test also has a few constructed response items. The domains covered in this assessment included basic computer operations (e.g., keyboard, disk drive, joystick, screen), software applications (e.g., word processing, graphics programs, database management systems, spreadsheets), and computer programming (e.g., LOGO, Basic, Pascal). Although the inclusion of hands-on performance tasks was initially proposed, such tasks were not included in the assessment because of the high costs of performance testing. Most of the test items were given to students in all the three grade levels, although some items were grade-level specific (e.g., questions on Pascal, a computer programming language, were given only to 11th grade students). (For details about the NAEP study in which this instrument was used, see Martinez et al., [1988] and NAEP [1986].)

The instruments developed for the IEA study and the OECD/CERI study were used for international studies of computer competence. The Functional Information Technology Test (FITT), used for the IEA study, was designed for use with primary students and lower and upper secondary students (the elementary level version of the test used a subset of items) (Pelgrum et al., 1993).[2] As the title indicates, the instrument focuses on functionality—"student prerequisites to functioning effectively with practical information-related tasks" (Anderson & Collis, 1993, cited in Pelgrum et al., 1993). Domains covered in FITT include basic operation of a computer, software applications (word processing, spreadsheets, and databases), and basic concepts of computer and information processing including questions on programming (BASIC, PASCAL, and LOGO).

Two instruments were developed for the OECD/CERI study (OECD/CERI ICT Program, 2000e): the ICT Skills and Concepts Test and the Information Test (OECD/CERI ICT Program, 2000e). These tests were designed for students from grades 7 through 12 and designed to assess ICT competency and information literacy (OECD/CERI ICT Program, 2000e).

Summary of Student Assessment Instruments

Very few technology proficiency assessment instruments could be identified that are suitable for a large-scale, statewide assessment program that is coupled with school accountability systems. (Additional instrument are in development; see below.) North Carolina and Virginia have the statewide assessment instruments that are aligned with the states' technology proficiency standards based on the ISTE-NETS standards. Instruments are used in Kansas for college admissions, although these instruments assess a relatively narrow set of technology proficiencies (as compared to the ISTE NETS standards). Only North Carolina attaches high-stakes decisions (high school graduation) to assessment of technology proficiency. In addition, various type of instruments are available for small-scale use. As we will discuss below, the technical qualities of

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[2] The 12 countries participating in the second stage of the IEA Computers in Education Study are Austria, Bulgaria, Germany, Greece, India, Israel, Japan, Latvia, Netherlands, Slovenia, Thailand, and the United States. The results of the assessment in Israel and Thailand are not available in the 1993 IEA report. A shorter version of the FITT (with 17 items) was used for elementary school students in the Netherlands and the United States (IEA, 1993).

these instruments are generally either relatively weak in terms of the instrument criteria for high-stakes testing (AERA/APA/NCME, 1999).

Post-Secondary Student/Adult Assessment Instruments

Instruments that measure the general technology proficiency of college students and adults are emerging as basic technology skills and knowledge become increasingly essential in the workplace. We identified seven instruments for post-secondary students and adults that fall into three types (the instruments reviewed in this section are presented in Table 9).

Table 9. Postsecondary/Adult Technology Proficiency Instruments

Purpose		Instruments Reviewed
High Stakes	**College graduation requirement**	Computer and Information Literacy Test (Utah State University) Computer Proficiency Exam (Southeastern Oklahoma State University) Technology Proficiency Examination (Adams State College)
	Course credits	CLEP: Information Systems and Computer Applications test (collegeboard.com) DSST: Introductory to Computing test (Chauncey Group International, Ltd)
	Certification	European (International) Computer Diverse License (ECDL Foundation) Tek.Xam (Virginia Foundation for Independent Colleges)

The first type is used in connection with graduation requirements applied to undergraduate students. Utah State University (USU), Southeastern Oklahoma State University (SOSU), and Adams State College in Colorado (ASC) all have developed such instruments. USU requires all undergraduate students, even those who have taken technology-related courses, to pass seven domain-specific tests as a condition for graduation (Utah State University, n.d.), while students at SOSU and ASC may choose to take technology proficiency assessment instead of completing a required technology course(s) (Southeastern Oklahoma State University, n.d.; Technology Proficiency Committee, Adams State College, 2000).

The second type of instrument is used to award credit to test takers who demonstrate skills and knowledge covered in a college-level technology course(s). These instruments are standardized tests developed and offered through national testing organizations. Students may choose to take these tests instead of taking relevant technology courses, although the tests are, in general, not associated with graduation requirements with which all undergraduate students must comply. Two such instruments were identified. One is the Information Systems and Computer Applications test offered through the College-Level Examination Program (CLEP) by the Collegeboard.com, an affiliate organization of the College Board (Collegeboard.com, 2001). The other instrument is the Introduction to Computing test, developed by the Chauncey Group International Ltd., which is part of the DANTES (Defense Activity for Non-Traditional Education Support) Subject Standardized Tests (DSST) program (Defense Activity for Non-Traditional Education Support Subject Standardized Tests, n.d.). Both tests assess relatively advanced knowledge of technology, including software development (e.g., software life cycle, programming logic) and system development, in addition to knowledge of basic operations of computers, software applications, and social and ethical issues related to information technology.

The third type of instrument is used for certifying test takers' basic technology skills and knowledge. These instruments are not designed for use in an educational context, but rather are designed to help college students and adults demonstrate their skills for prospective employers. We identified two such tests: the European (International) Computer Drivers' License (ECDL, or ICDL) and the Tek.Xam (developed by the Virginia Foundation for Independent Colleges, VFIC). The ICDL test of computer competence is administered in 32 countries, and was taken by more than 1 million people as of 2000 (European Computer Drivers License Foundation, n.d). VFIC completed the piloting of Tek.Xam in 2000 and has been administering it at approximately 30 higher education institutions in 2001 (P. Bouseman, pers. comm.., March 12, 2001). Nearly 50 corporations in various industries (e.g., banking, telecommunication, technology, media, health care, manufacturing) have endorsed the Tek.Xam (Virginia Foundation for Independent Colleges, n.d.).

Teacher Assessment Instruments

Instruments Used in Large-Scale/High-Stakes Assessment

Technology proficiency is now recognized as core skill area for teachers. Accordingly, various types teacher technology proficiency assessments are becoming available. We identified 19 instruments designed for assessing teacher technology proficiency. In general, these instruments were developed by universities or state committees for use in teacher training programs, and a variety of forms is now available (assessment types and formats and their advantages and limitations are further discussed in the next section). The instruments reviewed in this section are presented in Table 10. In addition to these direct measures, through the course of our search we also identified very many self-report (questionnaire) measures of technology proficiency, designed in the main for use in teacher professional development planning (these instruments were not included in our review, which focuses on direct measures).

Table 10. Teacher Technology Proficiency Instruments

Purpose		Examples
High Stakes	**Teacher credentialing/ certification (general)**	Idaho Technology Competency Exam (Boise State University) Idaho Technology Portfolio Assessment (University of Idaho and Lewis and Clark State College) Idaho Technology Performance Assessment (Idaho State University) Technology Portfolios (North Carolina)* Preliminary Educational Technology (California) Teacher Status Skills Test in ICT (UK)
	Teacher credentialing/ certification (vocational education)	Praxis II Subject Assessment (ETS) Computer Literacy/Data Processing Technology Education Office Technology Data Processing
Low Stakes	**Aid for learning/ professional development**	Teacher Universe Technology Integration Assessment Educational Technology Assessment (University of Connecticut) Level I Assessment Level II Assessment Level III Assessment

* Six Technology Portfolios were identified, developed by different public higher education institutions with teacher preparation programs in North Carolina. For details, see the Teacher Matrix, Appendix C.

While technology proficiency instruments for use in certifying teachers in business and technology education have been around since the late 1980s (e.g., ETS's Praxis II Subject Assessment Program), additional instruments are now emerging that assess the general technology proficiency of teachers, regardless of the subject matter and grade levels that they teach. These instruments are typically designed for use with pre-service teachers, and the successful performance on or completion of these assessments is often part of teacher certification requirements. Currently, this type of instrument is in use in Idaho, North Carolina, and California.

We identified few technology proficiency assessment instruments designed for use with in-service teachers for high-stakes decisions. The instruments used in Idaho are an exception; both pre-service and in-service teachers in Idaho must pass one of the technology proficiency assessments (of various formats and types) approved by the Idaho State Board of Education.

Although the assessments used in California and North Carolina are also designed for teacher credentialing purposes, they differ quite significantly in terms of target population and format. The Preliminary Educational Technology Test, which is currently under development by the California Commission on Teacher Credentialing, is designed for out-of-state teacher candidates seeking a preliminary multiple- or single-subject credential in the state of California. The technology proficiency test will be offered as an alternative to completing a teacher preparation program that has satisfied the technology proficiency requirements set forth by the Commission. This paper-and-pencil test includes 100 multiple-choice questions and two constructed-response items (N. Amador, personal communication, April 9 and 16).

North Carolina uses a portfolio designed to assess the technology proficiency of all pre-service teachers. State college teacher training programs are allowed to develop their own Technology Portfolios, which require tasks that demonstrate five advanced competencies as defined in the state's teacher technology proficiency standards. We identified seven such portfolios used in teacher training programs the state, most of which are either Web-based or computer-based (detailed information about each of these portfolios is found in the Teacher Instrument Matrix, Appendix C).

The ETS Praxis II Subject Areas Assessments Program includes four technology proficiency assessment instruments used in a number of states for the purpose of certifying teachers in business and vocational education. These paper-and-pencil instruments comprise 77 to 100 multiple-choice items (Education Testing Service, 2000b). The domains covered in these tests include computer literacy, data processing, office technology, and a broad range of industrial technologies (e.g., technologies in construction, manufacturing, energy, and transportation) (detailed information about each of these instruments is found in the Teacher Instrument Matrix, Appendix C).

While each of the instruments described above samples a fairly broad range of general skills and knowledge related to use of technology and integration of technology in instruction, another more targeted approach to teacher certification may be emerging, which involves developing a suite of assessments, each of which targets more specific technology competencies. For example, the Association for Educational Communications and Technology's (AECT) Project aims to define 37 role-specific technology competencies (Association for Educational Communications and Technology, n.d.). Examples of teacher roles include "Pre-Kindergarten", "Middle School Math", "High School Science: Physics", and "High School Language and Arts." The underlying premise of this approach is that necessary teacher technology proficiencies vary across subject matter and grade levels taught. Thus the teacher roles identified by AECT are both grade-level and subject-matter specific. The AECT project plans to develop a Web-based program that will certify that pre-service and in-service teachers who are prepared to use technology in their specific teacher roles. These assessments are to use a combination of self-assessment, peer-assessment, and expert-assessment procedures (ibid.).

Instruments Used in Low-Scale/Low-Stakes Assessment

Only four direct measure instruments were found for low-scale/low-stakes decision purposes. One instrument was developed by Teacher Universe, while the other three were created by the Neag School of Education at the University of Connecticut (UConn). Although both instruments are used to guide teacher professional development, their foci and targeted populations are slightly different. The Teacher Universe Technology Integration Assessment focuses on helping school leaders improve their technology training program by providing them with technology proficiency data of in-service teachers (Teacher Universe, 2000). The UConn Educational Technology Assessment program comprises three levels of assessment each using different instruments (Neag School of Education, the University of Connecticut, 2001). The program aims to assist individual teachers—both pre-service and in-service—in acquiring skills and knowledge that are essential for effective technology integration. Both instruments accommodate both inexperienced and experienced teachers. The Teacher Universe online instrument adapts the difficulty of the questions to the specific skill level of each test taker, while the UConn online assessment program comprises three assessments for three levels of technology proficiency. The first-level assessment focuses on basic operation of application software, while the second- and third-level assessments measure teacher readiness and performance in integration of technology into their teaching.

Although very few direct measures were found for use in low-stakes assessment contexts, as with the collection of student small-scale/low-stakes decision instruments, our search brought to light many self-report measures of teacher technology proficiency. Many of these self-assessment instruments are used for professional development planning or evaluation purposes, providing information about teachers' levels of technology proficiency. Most of these instruments were developed by private companies, national and regional research institutions, or teacher training programs, and are in use at the district or school level. However, several states offer self-assessment instruments. Examples of such instruments are the Kansas Technology Fluency On-Line Survey, the Utah Technology Awareness Project Self-Assessment, the California

Technology Awareness Project (CTAP) Self-Assessment, the North Carolina Technological Competencies for Educators, and the North Dakota Professional Competency Continuum Online-Assessment tool.

Several teacher self-assessment instruments are used for research purposes. As with the student instruments that are for research purposes, these teacher surveys include not only items on skills and knowledge but also those on teacher technology uses, attitudes, and briefs. This type of self-report measure can be found in Teaching, Learning, and Computing 1998: A National Survey of Schools and Teachers Describing Their Best Practices, Teaching Philosophies, and Use of Technology (Becker et al., 1999) and the OECD/CERI Study on the Impact of ICT on Student Learning (OECD/CERI ICT Program, 2000e).

Administrators

No direct measures were found that specifically assess technology proficiency of administrators. A few self-assessment instruments for administrators have been developed along with those for teachers. Examples are the North Dakota Professional Competency Continuum Online-Assessment tool and the Grand Island Public Schools Non-Instructional Staff Survey. In addition, online surveys specifically targeted at school and district technology coordinators are developed as part of the Integrated Studies of Educational Technology, funded by the U.S. Department of Education.

Instruments in Development

We identified several ongoing technology proficiency assessment development efforts. This suggests that technology proficiency assessment is an emerging field, and its landscape is likely to change rapidly in the next few years.

The teacher technology proficiency assessments are being developed in three efforts. The first ISTE initiative and is based on NETS Standards for Teachers. Following the development of the standards, an assessment framework has been proposed to continuously evaluate the growth of teachers' technology competencies. This framework covers a considerably long period of time from the entry into a teacher preparation program to when teachers are actually teaching in the classrooms (Barrett, 2001). In this framework, a portfolio assessment is used throughout the teacher preparation program as well as the teacher's professional life. In addition, other types of assessment have been suggested at the four crucial moments of the teacher's professional life so that high-stakes decisions such as course placements, certifications, and endorsements can be based on the assessment results. These four moments when the assessments are proposed include the first year and last year of the teacher preparation program, the first year of teaching, and after several years of teaching (Barrett, 2001).

To put the assessment framework into practice, ISTE and its collaborators (the University of Alaska, Anchorage, Apple Computer, EDmin.com, Teacher Universe, and MC-Squared) have prepared a proposal for the Knowledge Development Catalyst Grant program to develop online assessment instruments that can be used through all phases of teacher training and professional development (ISTE et al., 2001). Also proposed is the development of an online clearinghouse that links standards, artifacts, and evidence for portfolios and other assessments (ISTE et al., 2001).

The second development effort is initiated by the Association for Educational Communications and Technology (AECT). Supported, in part, by the PT 3 grant from the U.S. Department of Education, the AECT Project has been carried out to develop technology proficiency standards for teachers, which are both grade-level-and subject-specific. The project also plans to develop certification programs, for pre-service and in-service teachers, which are based on the new standards under development. In collaboration with Pennsylvania State University and other organizations, 37 specific teaching roles that require the use of technology have been identified (AECT, n.d.). As of July 2001, specific standards for each of the 37 teaching roles are still in development. Also being developed is the website that enables teachers to submit evidence and peer reviews of their mastery and practices of the role-specific competencies that will be identified in the standards (ibid.).

A third instrument development effort is being carried out by the California Commission on Teacher Credentialing (CCTC) in collaboration with the National Evaluation Systems (NES). CCTC has been developing the paper-and-pencil Preliminary Educational Technology test, which will be specifically targeted at out-of-state teacher candidates seeking a preliminary multiple- or single-subject credential in the state of California. The test will be given to such candidates as an alternative to completing a teacher preparation program in the state. The test will satisfy the technology proficiency requirements set forth by the Commission. As of April 2000, the test specification had been reviewed by teachers and teacher educators as well as the Commission's Bias Review Committee and Content Advisory Committee. Additional technical quality studies on scoring of constructed response items (two such items will appear in the test with 100 multiple-choice questions) as well as on a passing standard are to be implemented by NES in 2001 (N. Amador, pers. comm., April 9 and 16).

Conclusions and Recommendations

General Conclusions and Recommendations

State standards for student technology proficiency achievement have become pervasive. The ISET Survey found that 31 states have technology proficiency standards for students. However, currently state assessment of students' progress toward technology proficiency achievement objectives is limited, with only eight states reporting some kind of assessment of student of technology proficiency.

The field of technology proficiency assessment suffers from a lack of research and evaluation bearing directly on assessment in this domain. Research articles that address definitions and conceptualizations of technology proficiency only rarely address issues related to assessment or the formulation of standards. While there is a literature on computer literacy assessment, this framework is now dated (Venezky, 2001) and does not align well with current major standards for technology proficiency. In addition, research is needed to determine what data are need for educators and policy-makers related to student achievement of technology proficiency.

There is a lack of research on formulation of standards for student technology proficiency. What is particularly needed is research and policy analysis that examines the following topics: (1) The developmental trajectory of technology proficiency acquisition; (2) how technology change ought to be taken into account is the formulation of technology proficiency standards; and (3) the relative merits and consequences of states use of stand-alone technology proficiency standards vs. integrated technology proficiency standards.

Research in this domain is insufficient to support any conclusions as the benefits to students of implementing large-scale assessment of technology proficiency. High-quality assessments are costly and time-consuming to develop and implement. It seems clear that technology standards and assessments ought to keep pace with technology change, as it impacts instruction and career-readiness. However, it is unclear whether the relatively slow rate of development, adoption, and updating of state-mandated, large-scale assessments would create a barrier to the maintenance of up-to-date, appropriate assessments of technology proficiency. In addition, there is no research bearing on the question of whether technology proficiency assessment supports greater student progress in this domain.

The limited large-scale assessment by states in educational technology proficiency has implications for the design of the National Educational Technology Trends Study (NETTS), currently being planned. Only three states report assessing student technology proficiency using stand-alone assessments. Four states reporting assessing technology proficiency in core subject area tests. The limited availability of achievement data across states will limit the generalizability of data on achievement in technology proficiency. Where assessment is conducted, comparability of data collected with these assessments limited, for two reasons: Frameworks for technology proficiency assessments differ; and test items that are designed to assess technology proficiency and embedded in subject-area tests may not be comparable across tests. This presents barriers to the aggregation of technology proficiency achievement data collected with different instruments.

Technology Proficiency Assessment

At present, few instruments are available for assessment of technology proficiency of K-12 students and teachers, and fewer still are suitable for use in high-stakes decisions, when evaluated against professional standards for high-stakes testing (AERA/APA/NCME, 1999; Chronbach, 1990). Given that technology proficiency standards are relatively new, beginning to appear only within the last several years, this is not surprising. However, the need for high-quality technology proficiency assessments is growing as more states and districts develop technology proficiency standards, as technology becomes increasingly used in and necessary to instruction, as outcome data bearing on the effects of educational technology use are more in demand by educators and policy makers, and as technology in the economy becomes ever more pervasive. However, because the majority of states that have technology proficiency standards (31 states) have standards that are integrated with subject area standards (21 states) rather than stand-alone technology standards (9 states), the development of standards may not be a strong driver for the need for technology proficiency assessments. States that have integrated technology standards will not be as likely to opt for independent tests of technology proficiency.

Very few assessments exist for in-service teachers and administrators. Assessments that promote continuous learning of technology skills and the ability to integration into education are needed for today's in-service teachers, as well as for the in-service teachers of tomorrow, whose technology skills may well be out of date.

Leading experts in educational technology argue that technology in schools should be mastered and used, by both teachers and students, as a means to an end rather than an end in itself. However, by and large, assessments of student technology proficiency measure technology-related skills and knowledge decontextualized from any problem-solving or learning context.

At present, the functional/applications perspective on technology proficiency dominates assessment although it aligns only minimally with most current skill standards for the domain. While most technology proficiency standards for students encompass a fairly wide range of complex concepts and skills related to technology proficiency, such as use of technology to solve problems and evaluation of information, most existing measures of technology proficiency measure a comparatively narrow range of technology skills, such as use of productivity computer applications and basic computer operation. Complex abilities and higher thinking skills are hardly assessed by the existing instruments. This is not surprising considering that the technology proficiency assessment is still in its early stages of development. Methods of assessment other than paper-and-pencil, selected-response tests, such as demonstration and observation assessment, should be considered as options for assessing technology proficiency of students and teachers.

The teacher technology proficiency assessments reviewed for this study tend to go beyond the assessment of narrow technology skills, such as use of computer applications, to assess teachers' ability to use technology in instruction and as a tool to support professional practices. In this respect, teacher assessment instruments are generally stronger than those available for students. However, in general, teacher technology proficiency assessments in use in state college teacher training programs, which are often portfolio assessments, are generally not developed in keeping with the professional standards of assessment development and validation.

Most national and state technology proficiency standards and performance indicators are not specific enough to generate valid assessment frameworks, particularly those related to advanced technology-related competencies (for teachers, technology integration capabilities and for students, technology use for problem solving, completing complex tasks and gaining better understandings of content knowledge). Such standards frameworks cannot easily be adapted to assessment frameworks, and are likewise not effective in guiding educators in curriculum design.

Studies are needed that directly address the question of test frameworks and design for technology proficiency. Baker and O'Neil (1998) and Venezky (2001) are examples of the types of study that are needed; however, their analyses are not informed by considerations of the types of attainment data that are needed for policy makers or by educators. In addition, research on assessment of technology proficiency ought to consider issues pertaining to assessment type (performance, portfolio, multiple choice) and the relative merits of different types in terms of development and administration costs, construct validity, and impact on instruction.

Several factors may suppress the overall pace of development and use of high-quality technology proficiency assessments suitable for large-scale testing programs. Besides the high cost associated with instrument development and test administration, the following issues particular to the domain of technology proficiency assessment may be relevant. (1) Unlike the case with mathematics and reading, there is less consensus across states, national organizations, scholars, and educators regarding how the domain of technology proficiency should be defined, precisely how standards should be formulated and implemented, and what proficiencies should be specified across grade levels. (2) In some states, technology proficiency standards are integrated into disciplinary standards. In this context, technology proficiency is not likely to be assessed independently of disciplinary testing programs, and therefore the demand for technology proficiency assessments is not as great.

Although there is little consensus about what technology proficiency data should be collected to inform policy makers and general public, some sophisticated, comprehensive technology integration programs have developed self-assessments for use in staff development and program evaluation. Research institutes have been developing comprehensive evaluation frameworks and/or programs for technology implementation (e.g., "seven dimensions" approach by the Milken Exchange and the EnGauge program by the North Central Regional Educational Laboratory /NCREL). Perhaps such programs should be encouraged to develop high quality assessments aligned with their programmatic recommendations.

Technology Proficiency Standards

National technology proficiency standards developed for students give much greater attention to the changing nature of technology than do the standards for educators. Whether this is because attention to technological change is expected to be embedded with ongoing self-development on the part of professional educators or whether it is because scant attention has been devoted to the subject is unclear. However, it may advisable for these standards to articulate exemplar strategies for keeping up with new technological developments.

There is a need for more developmental research on technology proficiency. Too little is known about how students develop the kinds of competencies outlined in most standards. Many standards attempt to define a range of skills appropriate to particular grade levels; however these linkages seem to be based primarily on assumptions drawn from teaching practice, rather than from rigorous research. While teaching practice may prove to be a useful guide for understanding what can be expected from students at different grade levels, it may be just as important to develop and refine research strategies for identifying trajectories or pathways of development to technology proficiency.

There is a lack of research bearing on the question of whether students fare better when states have integrated technology standards or stand-alone technology standards. Similarly, it is unknown at this point whether, at the secondary level, students are better served by a one-size-fits-all approach to technology standards or by a diversity of technology-related standards. Are common technology proficiency achievement standards needed in order to assure that all students achieve a minimum, “lowest common denominator” of proficiency with educational technology? Or rather is a diversity of standards necessary, at the secondary level, given the wide range of “technology niches” that are relevant to education and career readiness, such a multimedia, programming, Web design, engineering, and networking? By which approach are students better served? Other questions that could usefully be addressed in relation technology standards include the following: Whether the presence of student technology proficiency standards serve as a driver for the integration of technology in the curriculum, above and beyond what other technology initiatives may accomplish; whether students in states with technology proficiency standards fare better in access to and mastery of technology proficiency; and whether states that adopt technology proficiency standards also institute procedures or policies related to updating or amending these standards, and the consequences of doing so or not.

Caveats, Challenges, and Opportunities

Given the lack of research and knowledge related to technology proficiency standards and assessments, states should proceed with caution in developing and implementing standards and assessments for students. It may be beneficial for experiment with variety of approaches to standards and assessments in order for best practices in this domain to be developed. States should share information regarding practices and outcomes so that the merits and disadvantages of different strategies can be assessed and weighed.

Because assessment systems can affect classroom instructional practices (Lane, Parke, & Stone, 1998), planning and implementation of assessment and accountability systems for technology proficiency should investigate consequential validity of the measures, to ensure that measurement of comparatively narrow technology proficiency skills and concepts does not negatively affect instructional practices and curriculum related to technology proficiency or narrow the range of skills and concepts addressed in classrooms. Incorporation of more complex technology-related skills into assessments will more clearly signal, in alignment with research on teaching with technology, that teachers should incorporate technology in ways allow students to master technology as a problem-solving and knowledge-construction tool.

Technology changes rapidly. This is true even for office software applications. It is uncertain whether specific computer applications skills that students learn in school and that are currently the focus of assessment will remain useful by the time today's 8^{th} graders enter the workplace. Clearly students need to have facility learning new technology, not just using it (Scardemalia & Bereiter, 1996). Assessing students' ability to adapt to new technology tools is an assessment challenge that is important for educators and test developers to tackle.

Equity in access to technology, at the student and school level, is important to address prior to implementation of assessment in technology proficiency. While opportunity to learn should be addressed for the implementation of any assessment program in the case of technology proficiency assessment, equity issues are important to investigate because within states, schools differ in their access to technology. Furthermore, research has shown that student performance on technology proficiency assessments is correlated with students' access to computers outside of the classroom. This has significant implications when the technology proficiency assessments are used as part of decision making that has high-stakes consequences for students. Data bearing on opportunity to learn is important in developing and implementing tests and in using test data for high stakes decisions.

The growing number of industry-based tests available for technical skills certification, and the penetration of the "IT guild" (Adelman, 2000) into the secondary level presents an interesting model for educational technology proficiency at the secondary level. Given the diversity of technologies and their uses at the secondary level, it may be that assessment at this level should be driven by a "personal needs" approach (Kay, 1993) that is based on students' interest and career trajectory. Rather than being assessed in technology proficiency at basic level in general applications, students could select from among a range of more specialized areas of technology proficiency in which to be assessed. In this scenario, suites of assessments could be developed that take into account the many, and continuously proliferating, roles of technology in the economy and in society. In such modular approach to technology assessment, new tests, which may be based in industry or education, could be added progressively and existing tests updated frequently. This has the potential to help states maintain up-to-date technology assessments.

Online testing has useful potential for the domain of technology proficiency assessment. Computer-based testing can make the assessment of complex skills and knowledge more cost-effective and efficient. The context of educational technology proficiency may be an especially suitable domain for computer-based testing because basic skills and knowledge in the domain are themselves technology-related; thus technology-supported assessment has the potential to support greater construct validity of tests. In addition, most technology standards call for students to use technology in the context of complex tasks and problems. Computer-based tests have the potential to assess these complex skills more cost-effectively than their paper-based counterparts. Research on technology proficiency assessment should consider the potential of computer technology to support the assessment of complex technology-related skills and the cognitive dimensions of technology proficiency, especially as the technical infrastructure needed in schools for computer-based testing is likely to be more prevalent in the near future years.

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