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ABSTRACT

This paper summarizes and extends an earlier study that reviewed the literature on technology effectiveness, focusing on computers, traditional distance education, two-way interactive telecommunications, multimedia, and the Internet. It also adds some tools for technology evaluation as well as a rationale for using regions to distribute information resources and services electronically. Traditional and emergent definitions of technology from various strands of research are examined, and a paradigm shift from a focus on student achievement defined by standardized tests to one of diverse indicators of learning and educational reform defined by recent research and Goals 2000 is identified. An analytic framework is presented to use the dimensions of technology. Part 1 presents an overview of the framework and its uses, while part 2 discusses the new consensus on learning, policy, and technology capabilities needed to support learning and reform. Part 3 considers trends in technologies and agencies, and part 4 presents a concept of regionality as a unit of operation. Part 5 notes critical steps for research, and part 6 explores policy recommendations. Four appendixes contain eight tables of supplemental data and cost checklists. (Contains 178 references.) (SLD)

Designing Learning and Technology for Educational Reform

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October. Version 1.0. The process of developing the tools and exemplary cases in this document is ongoing. This 1.0 version is the first release for the use of the tools in school-based contexts. As these tools are revised based on use, or more tools are developed, new versions of this paper will be developed and released.

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FOR EDUCATIONAL REFORM

Introduction

This paper is based in part on an earlier literature review on technology effectiveness conducted for the Illinois State Board of Education (see Jones, Valdez, & Rasmussen, 1994). The five technologies reviewed were computers, traditional distance education, two-way interactive telecommunications, multimedia, and the Internet. A major outcome of the earlier research was a framework to assist schools and policymakers in evaluating specific technologies and technology-enhanced curricula. This paper both summarizes and extends the earlier study. It also adds some tools for technology evaluation as well as a rationale for using regions to distribute information resources and services electronically.

In this review, we examine traditional and emergent definitions of technology effectiveness from various strands of research. We identify a major paradigm shift from a focus on student achievement defined solely by standardized tests to one of diverse indicators of learning and educational reform defined by recent research on learning and Goals 2000. This is a shift from traditional learning and course designs to models of learning involving more interactivity, more connectivity among schools, more collaboration among teachers and students, more involvement of the teacher as facilitator, and more emphasis on the technology as a tool for learning, collaboration, curriculum development, and professional development.

We present here an analytic framework using dimensions of technology and learning to create an optimum relationship between quality learning as we have come to know it and high performance technology. In this paper, we explore this framework and elaborate on it, looking at some of the issues people are dealing with in technology and learning and identifying how this framework can come into play.

This paper is organized into six parts. Part 1 presents an overview of the framework and its potential uses and importance for educators and policymakers. In Part 2, we discuss the new consensus on learning, policy, and the technology capabilities needed to support learning and reform. Part 3 considers trends in technologies and agencies that focus on networked information resources and developing learning communities. In Part 4, we present the concept of regionality as a unit of operation for technology; distribution of services and resources; and experimentation of new designs in technology, software, and agency. Part 5 notes some critical next steps for research. Finally, Part 6 explores policy recommendations following from the analysis as a whole.

1. Overview of the Technology Effectiveness Framework

The Technology Effectiveness Framework was developed to assist educators, researchers, and policymakers in evaluating technology and technology-enhanced programs/curricula against specific reform goals for a school, district, state, or service agency. It may also be used by schools to guide them as they select and work toward specific curricular goals to promote engaged learning. Additionally, researchers, curriculum developers, and staff developers could use this framework to design technologies and technology-enhanced programs.

The Analytic Variables for the Framework

The overarching concept that drives the framework proposed here is that technology effectiveness can be defined as the intersection of two continua (see Table 1 on following page). The horizontal axis is **learning**, which progresses from passive at the low end of the continuum to engaged and sustained at the high end. To help conceptualize this continuum, we selected a set of indicators for engaged learning and instructional reform, for which there is increasing consensus—developed by Means and her colleagues (1994)—and enhanced it by adding other indicators. The vertical axis is **technology performance**, which progresses from low to high. We define six indicators of technology performance derived from recent research on instructional design and technology-enhanced learning. Two sets of indicators are described in detail in Part 2.

When we cross the two continua, four major learning and technology patterns emerge:

Category A — Engaged learning and high technology performance
Category B — Engaged learning and low technology performance
Category C — Passive learning and high technology performance
Category D — Passive learning and low technology performance

The Value of the Framework

Using this framework, we have identified some major directions for policymakers to consider regarding resource and infrastructure support to schools, especially when using technology as a tool for classroom and school restructuring. Specifically, we noted four positive (desirable) trajectories:

1. Type I trajectory is D —> B. This is movement *from* passive learning and low technology performance *to* engaged learning and low technology performance.

TABLE 1

THE LEARNING AND TECHNOLOGY INTERFACE

TECHNOLOGY PERFORMANCE

Low ==> High

(C) **Examples** -Closed integrated learning systems focusing on low-level objectives and standardized, objective assessments -Traditional distance education used to transmit information from a central source and focused on low-level objectives and assessments (talking head) -Connections to homes that are linked only to closed networks for the school and vendor and perhaps to other schools using the same vendor	(A) **Examples** -Networked projects with challenging tasks; access to Internet; integrated multimedia capabilities including CD-ROM, two-way video conferencing, access to professionals - Distance education networked with computers; challenging tasks; linked to work with real-world professionals and data; two-way video -Advanced tools and high-technology museum exhibits that are interactive and support high-level thinking
(D) **Examples** -Computer-based instruction/drill and practice focusing on low-level objectives -Instructional television focused on low-level objectives -Video and audio used to transmit information as a lecture or talking head -Teaching a computer language or word processing as an end in itself as technology literacy	(B) **Examples** -Projects using multimedia experiences and data provided by CD-ROM for authentic and challenging learning -Local file sharing allowing students access to all files for communal editing and development -E-mail for inquiry collaborations -State network support for schools using the Internet for projects

Passive Learning ══════ Engaged Learning

LEARNING

2. Type II trajectory is B —> A. This is movement *from* engaged learning and low technology performance *to* engaged learning and high technology performance.

3. Type III trajectory is C —> A. This is movement *from* passive learning and high technology performance *to* engaged learning and high technology performance.

4. Type IV trajectory is D —> A. This is movement *from* passive learning and low technology performance *to* engaged learning and high technology performance.

It is obviously counterproductive to move from D (passive learning with the least functional technologies) to C (passive learning with more functional, and more costly, technologies. If a school or group is not using technology to enhance learning and reform, there is little reason to suffer the higher cost for greater functionality.

Movement from one Type to another depends not only on what curricular goals are important for the future but also on what configurations of learning and technology are in place now. Once new curricular goals are in place, the trajectories can be used as a very rough guide to what technologies are needed to move toward reaching these goals, using the learning and technology capacity indicators defined in the paper.

This framework also raises the question: How can we justify the added cost and effort to install high performance technologies if engaged learning can be attained without technology or with less expensive, low-performance technologies? We would argue that high-performance technology adds very substantial, qualitative differences to the learning environment that cannot be attained without that technology. Indeed, the high-performance technologies such as those listed in Table 1 essentially redefine many of the parameters that define schooling: where learning takes place, what constitutes the learning community, who is the teacher, who is a learner, what the primary instructional materials and resources are, what the tasks and assessments are, and who produces and controls information, as well as what the learning context is. Such technologies also require the development of concepts and strategies for a new way of learning that is often nonlinear and often involves communications that are asynchronous and simulcast to multiple locations and very complex tasks and tools not previously available to students. Finally, such technologies address issues of equity in that they significantly redefine opportunities to learn for students who are poor and lack local resources and for students who are academically at risk and might otherwise be assigned to low-level tasks.

When using this framework, the critical questions for schools in evaluating technology and the costs of technology are: What are the learning goals to which technology is applied? (At NCREL, we refer to these goals collectively as the vision for learning.) How are these learning goals moving the school toward reform? How will a technology-enhanced curriculum support instruction that addresses those learning goals? How does the technology-enhanced approach help restructure the school to meet its plan for educational reform? Do the students achieve the learning goals using the technology-enhanced curriculum? Can the school implement cost-efficient technologies given its goals and current realities? Can the school extend or adapt less functional technologies so that they are more functional to support a global community of learners in sustained learning that is challenging and authentic? Are there funding strategies/partnerships that can reduce the cost? How can a school continuously plan to use technology to reach for more powerful learning goals and reform?

The Importance of the Framework

When policymakers, educators, researchers, and others view the intersection of technology and learning, rather than just technology by itself, it is possible to link technology to issues of educational reform in important ways.

Issues of learning, reform, and technology are perhaps more critical than they have ever been for several reasons. First, there was major legislation enacted in 1994 with the Goals 2000: Educate America Act (PL103-227) that will provide significant attention to technology. In fact, additional technology funding to implement Goals 2000 is expected in federal legislation (see Ramirez & Bell, 1994). Recent research and practice on learning indicates that technology can play a critical role in changing classroom environments and school restructuring to promote more engaged and powerful learning. Indeed, some evidence suggests that technology may even accelerate these restructuring processes (see below). The framework proposed here could be used to design and evaluate proposals to address these initiatives.

Second, high-function technologies that are needed for Categories A and B are very expensive. It is critical for schools and others to be informed about the differences among technologies and technology-based programs and how they will be used to support learning that is linked to the standards. It is also imperative to consider how traditional distance education providers can move toward high performance technology configurations and engaged learning.

Third, decisions about technology, learning, and reform are critical because there is now an opportunity to reconfigure on a large scale how information and resources are delivered to schools and other agencies. Specifically, there is the opportunity to develop not only a national infrastructure, but also regional consortia that can distribute technology information and educational resources to intrastate and multistate regions, and that can provide regionally-based services to schools on-line and on site. Our framework proposes some innovative kinds of regional agencies to address these issues.

Fourth, if it is true that some technology-enhanced programs are much more powerful than others in their ability to generate engaged learning (e.g., Category A in our framework), then it is imperative to assure that all students have access to these powerful designs, or, at the very least, that access to those powerful designs is equitable. These equity issues occur in two different contexts. There is a significant disparity among those trained in technology and those less well educated. According to the *Economic Report of the President* (1994):

> Since the use of more-educated labor has increased in all industries, a logical explanation of this trend is technical change. For example, one study shows that people who work with personal computers earn a substantial wage premium over those who do not, and that this gap can account for half of the increasing gap between wages of college and high school graduates (p. 119).

In terms of equity in the context of education, the concern for equity is evident in Goals 2000, the technology legislation in progress indicated above, the focus on universal access in the Vice President's Agenda for Action speech (Gore, 1994), and language given below from the National Science Foundation (NSF). The administration and Congress are very aware of the disparities between affluent schools and schools for minority students and the poor and have generated provisions to facilitate assistance to the latter. There are provisions in the Goals 2000 legislation to facilitate linking the wealth of free materials in museums, libraries, the Internet, and other agencies to schools. There is even a strong awareness in the recent emphasis on universal participation from NSF (Sabelli & Barrett, 1994). There is increasing consensus everywhere that it is not enough to provide the technology and the connections so that everyone *could* participate; it is vital to provide ongoing professional development and new designs for technology-enhanced curricula so that everyone *will* participate.

If we believe that all students can learn, we must overcome barriers to participation and use by poor and minority schools. For schools with high populations at risk, it is important for policymakers to (1) provide opportunities for schools and students to become informed about and experience the best technologies and technology-enhanced programs building on the new consensus emerging around learning and technology; (2) establish curricula and assessment that reflect engaged learning to the highest degree for students at risk; (3) give schools permission and time to explore and experiment with new learning and instructional paradigms; and (4) provide ongoing professional development to develop new learner outcomes, curricula, and assessment that utilize the best technologies and programs (see also Collins, 1993).

Fifth, a major concern for research and policy is to anticipate that the poorest schools may need the most help in professional development and school restructuring. The framework could be used to (1) develop challenging objectives, (2) develop prototypes that transform free information resources into usable curricular and instructional formats to reach those objectives, and (3) evaluate the results of specific programs and initiatives.

Sixth, how can we ensure that poor schools, especially those with students who are academically at risk, have equitable opportunities to access and use technologies related to successful performance in the workplace and community? There must be ways, as Kati

Haycock recently remarked, that policymakers can help those with the greatest challenges "go to the front of the line." The regional infrastructures proposed in this framework could address this end in two ways. They can help distribute instructional and assessment services to the poorest schools that would empower them to utilize new information resources effectively. Additionally, regional infrastructures could be used to generate scenarios for how best to rethink school economies using technology and free information resources, to provide a forum for debate, and to monitor equitable participation in the national information superhighway.

In the next section, we summarize the research basis for this framework from Jones, Valdez, and Rasmussen (1994) and elaborate its uses and implications. Specifically, we cover the growing consensus against traditional models of learning and definitions of technology effectiveness; the emerging consensus on both learning and technology; learning and technology interactions and school-based policy; and local, state, and national policy issues.

2. The New Consensus

In recent years, there has been increasing consensus on learning and technology emerging from several strands of research. First, there are strong reactions against traditional models of learning, traditional definitions of technology effectiveness, and traditional models of cost effectiveness for the use of technology. Second, a very strong consensus is forming from research on the importance of engaged, meaningful learning and collaboration involving challenging, authentic tasks. Third, the recent research on learning is influencing, and being influenced by, our understanding of technology as a tool for learning and communication, yielding new criteria for technology's performance. Fourth, this consensus on learning and technology permits us to look at the intersection of learning and technology as two continua moving from passive to engaged learning and from low to high performance technology. Fifth, there are policy implications of this analysis.

Consensus against Traditional Models and Definitions

Across the nation, there is a growing concern that traditional models of learning based on the assembly model are not aligned to the needs of the 21st century. Specifically, the workplace and community need citizens who can think critically and strategically to solve problems, learn how to learn in a constantly and rapidly changing environment, build knowledge from distributed sources and multiple perspectives, understand systems in diverse contexts, and collaborate locally and around the globe both synchronously and asynchronously using technology (Berryman, 1988, 1992; National Center on Education and the Economy, 1990; Reich, 1991; (The Secretary's Commission on Necessary Skills [SCANS], 1992). These attributes contrast sharply with the discrete, low level basic skills and content taught in many schools. They also contrast with the transfer model of instruction, which assumes that the teacher is the information giver and the student a passive recipient, and with standardized tests that assess skills sometimes only useful in schools and that often do not measure what is taught.

There are also arguments from many sources against traditional definitions of technology effectiveness: that is, the practice of comparing the technology program to the traditional program in terms of student outcomes on standardized tests (see Jones, Valdez, & Rasmussen, 1994). However, we found that the most forceful comments came in e-mail communications from researchers in the field in response to NCREL's request for information on technology effectiveness. For example, Beverly Hunter argued that effectiveness is not a function of the technology, but rather a function of (1) the learning environment and (2) the capability to do things that one could not do otherwise. Moreover, "Technology in support of outmoded educational systems is counterproductive" (Hunter, personal communication, February, 1994; see also Hunter, in press). In another e-mail, Robert Blomeyer called the concern for standardized tests "ludicrous." He argues, technology works in a school not because test scores increase, but because technology empowers new solutions to learning and teaching needs (see also Blomeyer, 1991). According to Blomeyer, effectiveness must be documented in rich case studies.

The traditional way to measure cost effectiveness for technology is to compare a technology-enhanced program against the traditional model of learning. Some researchers caution against this definition/approach. Collins (1993), for example, voices a number of concerns about the research on the cost effectiveness of technology:

1. It is difficult to measure the efficiency of some technologies, such as word processing compared to typing. Word processing is obviously more costly, but we need to evaluate what would be lost by keeping the old technologies. Such cost analyses constantly assume that we should continue teaching the same things.

2. Cost effectiveness data would constrain developing innovative applications of technology.

3. It is not possible to control all of the variables in such comparisons. According to Collins, providing an alternative definition of cost effectiveness is self-defeating, since raising questions about cost effectiveness is the wrong thing to do. Our understanding of Collins' perspective is that schools should explore what learning can be empowered by technology that is otherwise not possible through research on a small scale. Then they can consider issues of scaling up and dissemination.

Herman (in press) also wonders why we keep asking the same questions when they are not the right questions. She sympathizes with the need for policymakers and others to have answers to questions about technology effectiveness on student learning, student readiness for workforce skills, teacher productivity using technology, and cost effectiveness. But she argues that we cannot find definitive answers across studies or across a given technology or configuration. Herman acknowledges that some examples of technology, such as Pogrow's

(1990), higher-order thinking skills program, HOTS, and the Jasper Series developed by the Cognition and Technology Group at Vanderbilt (1992b), show strong and consistent, positive results. However, she argues that even powerful programs might show no project effects due to a myriad of methodological flaws, and that it would be most unfortunate to reject them because measures on standardized tests showed no significant differences. Instead, she contends, we should develop theory-specific measures developed from a particular theory or model.

In essence, what we have learned from these reactions against traditional molds is that we must change the questions and the process. What is most important in judging technology effectiveness and cost effectiveness for technology is establishing a clear vision of learning and goals for a school, district, or other unit. Without a vision and goals for learning, there are no criteria for evaluating technology effectiveness or costs. A major issue is the extent to which the goals and the actual technology configurations used would support learning and other educational reforms versus traditional models of learning and schooling (Ramirez & Bell, 1994). A second major issue in thinking about cost effectiveness is that it should not be judged by comparing the costs of a technology or technology-enhanced curriculum to a traditional curriculum. Rather, we should consider various technologies and configurations to achieve the goals and develop effective strategies for funding—an important equity issue because poor schools do not to do this effectively.

Emerging Consensus on Learning

Research on Learning. Across many strands of research there is increasing consensus on (1) what are the key variables of learning and instruction and (2) what defines engaged learning in the classroom and school. Regarding the key variables of instruction, Jones (1992) identified eight variables, which have been updated as follows: (1) the goals and metaphors that drive learning and instruction, or what we at NCREL call the vision of learning; (2) the tasks that ultimately define the nature and level of achievement as well as the curriculum; (3) the assessment principles and practice; (4) the instructional model; (5) the characteristics of the learning context including the nature of the learning environment, and the nature of the relationship among teachers and students; (6) grouping arrangements; (7) the learner roles; and (8) the teacher roles. These are all neutral terms that could describe analytically any classroom or learning environment.

Regarding what defines learning in the classroom, there is a rich body of literature from various fields that must be examined. Consider, for example, theories/concepts such as the **"new" definition of reading** (e.g., The Report of the Commission on Reading, 1985); **anchored instruction** (Bransford et al., 1990); **metacognition** (Brown, 1978); **cognitive apprenticeship** (Collins, Brown, & Newman, 1989; see also Collins, Brown, & Holum, 1991); **multiple intelligences** (Gardner, 1990); **learning and teaching using the Internet** (Hunter, in press); **reciprocal thinking** (Palincsar & Brown, 1984); **communities of practice** (Roupp, 1993); **education and learning to think** (Resnick, 1987); **thinking curriculum** (Resnick & Klopfer, 1989); **cognitive flexibility** (Spiro & Jehng, 1990); and

distributed intelligence and knowledge-building communities (e.g., Pea, 1992). Each of these theories of learning/instruction speaks to the eight variables and provides a rich profile of what engaged learning is about and what conditions are necessary or optimal in the learning environment to yield engaged learning. An examination of this literature reveals not only multiple perspectives and unique constructs but also many common assumptions. These commonalities exist in part because of common connections to such theorists as Dewey, Vygotsky, and Whitehead and in part because of major paradigm shifts in thinking in the disciplines and other areas.

What are these common assumptions? What are the indicators of engaged learning when we examine each of the variables in the Jones (1992) framework? There are numerous efforts to capture these commonalities in research syntheses and principles of learning that cut across the research on learning and instruction; e.g., the learner-centered principles developed by the American Psychological Association (1993); the principles for meaningful classroom learning developed by Brooks and Brooks (1993); cognitive designs in education (Jones, 1992); and the indicators of reform instruction articulated by Means and her colleagues (1993). From these efforts, we have selected the indicators developed by Means and her colleagues as a vehicle to develop our analytic framework. Our reasons for selecting this analysis are: their work was based on much the same literature/theories of interest here; the framework was grounded in observations of successful practice and covers all of the variables that define instruction; and because they link the use of technology in the classroom to learning and educational reform.

Specifically, Means and her colleagues developed a report for the Office of Educational Research and Improvement (OERI) that argues that technology should be measured by the extent to which technologies and technology-based programs support rich learning opportunities and educational reforms. Toward that end, they developed seven indicators to measure effective learning and reform instruction. These indicators are **authentic and multidisciplinary tasks, performance-based assessment, interactive modes of instruction, heterogeneous groupings, collaborative work, student exploration, and teacher as facilitator**. In a personal communication, Means emphasized that authentic tasks are the driving indicator of what she calls "reform instruction" in that all of the other features follow logically if authentic tasks are in place. Authentic tasks address important issues and problems in the real world. Such tasks usually involve collaboration, heterogeneous grouping, performance-based assessment, and sometimes exploration. Also there is usually some kind of facilitator.

In this groundbreaking work, Means and her colleagues applied these indicators to 44 technologies and technology-based programs in order to reveal the extent to which each one supports learning. We will return to this analysis at appropriate points in the section on learning and technology interactions. For the present, it is important to discuss the learning indicators in their framework.

We agree with the focus these researchers selected in defining each indicator and also with the essence of their definitions. However, the definitions provided by Means and her colleagues allow considerable latitude in interpretation, and it would not be too difficult for some users of their indicators to think that they already have these things in place when in fact they may not. In our descriptions of these indicators below, we have added one variable—the vision of learning that is the foundation for reform instruction, what we call *engaged learning*. Second, we have enhanced these definitions to reflect more of the recent research on learning and instruction referred to above (much of which was not available to Means and her colleagues) and to leave less opportunity for reductionism. Note that there is some amount of symmetry and redundancy as one looks at the set of eight indicators as a coherent whole. That is, if the instructional model is generative, then assessments should be generative also. Similarly, if the learning context values diversity, then other categories of learning such as grouping and assessment should reflect that value also.

1. Indicators: Vision of Engaged Learning. What does engaged learning look like when you see it in students? What is the vision of engaged learning that should drive the development of tasks, instruction, assessment, learning contexts, and student and teacher role definitions? Combining knowledge from research and best practice, we would define engaged learning in terms of four indicators (see also Jones & Fennimore, 1990; Tinzmann et al. 1990). First, students are *responsible for their own learning*; they take charge and are self-regulated. They define learning goals and problems that are meaningful to them; they have a big picture or blueprint of how specific activities relate to those goals; and, using standards of excellence, they evaluate how well they have achieved the goal(s). Successful, engaged learners also have explicit measures and criteria for assessment and self-assessment as well as benchmark activities, products, and/or events for checking their progress toward achieving their goals. They have some optional routes or strategies for attaining the goals and some strategies for correcting errors and redirecting themselves when the plans and strategies are not working. Being responsible and taking charge also means knowing one's strengths and weaknesses and how to deal with them both productively and constructively as well as how to shape and manage change.

Second, successful, engaged learners are *energized by learning*. They derive excitement and pleasure from learning so that it is typically intrinsically motivating and yields a lifelong passion for solving problems; understanding; and taking the next step in their thinking, research, or creative production.

Third, these learners are *strategic*; they know how to learn because developing and refining learning and problem-solving strategies are ongoing for them. This capacity for learning how to learn includes constructing effective mental models of knowledge and resources even though the information may be very complex and changing. Strategic learners can apply and transfer knowledge to solve problems creatively as well as make connections at different levels.

Fourth, successful, engaged learning involves being *collaborative*: valuing and having the skills to work with others. Collaborative learners understand that learning is social, that they must be able to see themselves and ideas as others see them, must be able to articulate their ideas to others, and must have empathy and be fair-minded in dealing with contradictory or conflicting views. They have an ability to identify the strengths of others and the diversity of one's own strengths and intelligences. Collaborative learners typically value diversity and multiple perspectives.

2. Indicators: Tasks for Engaged Learning. As indicated above, Means and her colleagues indicated that in successful schools, tasks are *challenging*,* *authentic*,* and[1] *multidisciplinary*.* In terms of being challenging, such tasks are typically complex and involve sustained amounts of time compared to tasks typically offered in schools. We find that tasks in the most effective schools also require students to stretch their thinking and often their social skills in order to be successful. Challenging tasks are authentic in a number of ways (see Hunter, in press). They correspond to the tasks in the home and workplaces of today and tomorrow. They have a close relationship to real world problems and projects, build on life experiences, require in-depth work, and benefit from frequent collaboration. Collaboration often takes place with peers and mentors within school as well as with diverse people in the real world outside of school. Tasks are also authentic when they represent projects and problems of relevance and interest to the learner(s). Authentic tasks merit authentic audiences, whether they be peers engaged in author-reader response groups reacting to their original writing or practitioners in the field reacting to student projects. Challenging, authentic tasks incorporate the knowledge of the disciplines and the ways in which they are used by practitioners. Students learn authentic tasks in context, practicing basic and advanced skills together as a means to learning the big concepts. They also learn something at the time it is needed for a project or problem. Authentic tasks usually involve and benefit greatly from multidisciplinary work. That is, challenging and authentic tasks often require wholly integrated instruction, which blends disciplines entirely into thematic or problem-based pursuits, and instruction that incorporates problem-based learning (PBL) and curriculum by project (CBP).

3. Indicators: Assessment of Engaged Learning. Assessments to promote engaged learning involve presenting students with an authentic task, project, or investigation, and then observing, interviewing, and/or examining their artifacts and presentations to assess what they actually know and can do. In such *performance-based** assessment, students construct the knowledge and create the artifacts that represent their learning. Ideally, students are also involved in generating performance criteria and are instrumental in the overall design, evaluation, and reporting of their assessment. In this way, the assessment is truly *generative*. The overriding purpose of assessment is to improve learning. To that end, assessment should closely match the goals of the curriculum; represent significant knowledge and enduring skills, content, and themes; and provide authentic contexts for performance.

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[1] Asterisks represent indicators identified by Means and her colleagues.

The performance criteria should be clear, well articulated, and a part of the student learning experience prior to assessment. Indeed, developing standards of excellence for learning and thinking is an important part of learning. Students should have internalized the performance criteria to the extent that they know when they have met their learning goal. Any rubrics used should be tailored to fit the context of the performance task.

Performance-based assessment, at its best, is *seamlessly interwoven with curriculum and instruction so that it is ongoing*. Therefore, assessment should represent all meaningful aspects of performance. It should encompass the evaluation of individual as well as group efforts; self-, peer, and teacher assessment; attitudes and thinking processes; drafts/blueprints/artifacts of developing products as well as the final products; open-ended as well as structured tasks; and tasks that emphasize connections, communication, and real world applications. Multiple measures, e.g., surveys, inventories, journals, illustrations, oral presentations, demonstrations, models, portfolios, and other artifacts of learning, are often needed to assess big ideas and complex learning outcomes over time.

Issues of equity in the type of performance-based assessments described above are linked to issues of standards. It is critical to have *equitable standards*; that is, ones that apply to all students. Both parents and students should be familiar with those standards and be able to evaluate the performance of an individual or group against them.

4. Indicators: Instructional Models and Strategies for Engaged Learning. The most powerful instructional models or modes are interactive and generative by design. *Interactive** instruction actively engages the learner. It can also be *generative*, encouraging the learner to construct and produce knowledge in meaningful and deep ways. Generative models of instruction have as their goal providing experiences and learning environments that promote deep, engaged learning in students. Further, whereas traditional models conceive of learning as a two-person situation (the teacher and student), generative models assume that learning is a three-person situation (the teacher, the student, and others) so that there is co-construction of knowledge—students teach others interactively and interact generatively with the teacher and peers. There may also be knowledge building as persons from multiple perspectives interact to produce shared understandings.

Generative approaches, such as reciprocal teaching, utilize a wide range of instructional strategies. These instructional strategies include Socratic dialogue, individual and group summarizing, means of exploring multiple and differing perspectives, techniques for building upon prior knowledge, brainstorming and categorizing, debriefing, content-specific as well as general problem-solving processes, team teaching, and/or techniques for constructing mental models and graphic representations. All of these models and strategies encourage the learner to solve problems actively, conduct meaningful inquiry, engage in reflection, and build a repertoire of effective strategies in diverse social contexts for learning.

5. Indicators: Learning Context for Engaged Learning. The classroom, when conceived as *a knowledge-building learning community*, resists fragmentation and competition and enables students to learn more collaboratively and academically. Such communities not only develop shared understandings *collaboratively*, assuming that intelligence is distributed among the members, but also create *empathetic learning environments* that value diversity and multiple perspectives. Such communities search for strategies to build on the strengths of all its members. These features are especially important for learning situations in which there are marked differences in prior knowledge. For example, while individuals may have very different levels of knowledge or expertise about a topic, knowledge-building strategies, such as brainstorming what is known about a topic, collaboratively pool the knowledge and experiences of the group, thereby creating more equitable learning conditions for everyone.

Classrooms, schools, and communities that are truly collaborative encourage all students to ask hard questions; define problems; take charge of the conversation when it is appropriate; participate in setting goals, standards, benchmarks, and assessments; have work-related conversations with various adults in and outside of school; and engage in entrepreneurial activities at times. This vision contrasts sharply with classrooms in which interactivity is defined as students responding enthusiastically to questions posed by the teacher. Collaborative classrooms also contrast with cooperative learning paradigms when they involve highly structured tasks and student roles defined and controlled by the teacher (see NCREL, #3, 1990). Collaborative work may be most powerful when it is in the context of flexible, learning-centered investigations that involve students with practicing professionals and community members. Such collaborations may occur electronically or in work outside the school.

6. Indicators: Grouping for Engaged Learning. Collaborative work that is learning centered often involves small groups or teams of two or more students within a classroom or across classroom boundaries. Although the role(s) and task(s) of each student may be different, all members of the group collaborate to accomplish the group's goal or project. When a task is complex or creative in nature, it is often beneficial to use *heterogeneous** grouping. Groups that include males and females and a mix of cultures, learning styles, abilities, socioeconomic status, and ages bring a wealth of background knowledge and differing perspectives to authentic, challenging tasks. Many teachers make use of *flexible* grouping, configuring and reconfiguring their small groups according to the purposes of instruction. This enables them to make frequent use of heterogeneous groups and to form groups, usually for short periods of time, based on common interests or needs. Flexible grouping, incorporating recurrent use of heterogeneous groups, is one of the most *equitable* means of grouping and ensuring increased opportunities to learn to all students.

7. Indicators: Teacher Roles for Engaged Learning. The role of the teacher in the classroom has shifted and greatly expanded from the primary role of information giver to that of facilitator, guide, and learner. As *facilitator,** the teacher provides rich environments, learning experiences, and activities for learning, incorporating opportunities for collaborative work, problem solving, authentic tasks, and shared knowledge and responsibility. Such a collaborative classroom requires the teacher to act as a *guide*—a complex and varied role that incorporates mediation, modeling, and coaching (see NCREL, #3, 1990). When mediating student learning, the teacher is frequently adjusting the level of information and support needed by students and helping them to link new information to prior knowledge, refine their problem-solving strategies, and learn how to learn. Teacher modeling involves thinking aloud and demonstrating, when needed. Coaching involves giving hints or cues, providing feedback, refocusing student efforts, assisting students in the use of a strategy, and providing procedural and factual knowledge in authentic contexts, when needed. The teacher as guide relies heavily on active listening skills and Socratic questioning techniques.

Given the diverse opportunities and challenges present in education, the teacher is often a *co-learner* and *co-investigator* along with the students. That is, as teachers and students participate in scientific and other investigations with practicing professionals, increasingly they will need to explore new frontiers and become producers of knowledge in knowledge-building communities. Indeed, there will be times, especially with technology, when students are the teachers and teachers are the learners.

8. Indicators: Student Roles for Engaged Learning. One important student role is that of *explorer.** Students discover concepts and connections and apply skills by interacting with the physical world, materials, technology, and other people. Such discovery-oriented exploration provides students with opportunities to make decisions while figuring out the components/attributes of events, objects, people, or concepts. Often students are encouraged to jump into an open-ended activity in order to stimulate their curiosity, become familiar with the instructional materials, and formulate early understandings of the task. Students can then reflect upon ideas and revise, reorganize, and expand upon their understandings with further knowledge, exploration, and debriefing. Reflective thinking is also essential for the student as *cognitive apprentice* (e.g., Collins, Brown, & Holum, 1991). While the student is engaged in challenging authentic tasks and co-investigations, apprenticeship learning takes place when the student observes, applies, and refines through practice the thinking processes used by practitioners. Students can then reflect on their practice in diverse situations and across a range of tasks and articulate the common elements of their experiences. This will enable them to generalize their skills and transfer their learning to new situations. In cognitive apprentice roles, learning experiences are essentially formative with feedback on a day-to-day basis over many aspects of a complex problem or skill. There are significant occasions, which we predict will occur more with effective technology use, when students need summative (role) experiences. When students are *teachers*, they integrate and represent holistically what they have learned intensely over a period of time, thereby yielding deep generative learning. Similarly, when students are *producers of knowledge*, they generate products for themselves and the community at large that synthesize and integrate knowledge and skills holistically. Moreover, as we shall see throughout this paper, increasingly students, through the use of technology, are able to make what practicing professionals consider to be significant contributions to the world's knowledge.

Table 2 on the following page summarizes the indicators for each of the eight variables of learning and instruction. The left column shows the neutral, analytic variables for learning and instruction. The right column provides specific indicators of engaged learning

TABLE 2

ENGAGED LEARNING AND REFORM INSTRUCTION

Variables of Learning and Instruction	**Indicators for Engaged Learning and Reform Instruction**
Vision of Learning	Responsible for learning Strategic Energized by learning Collaborative
Tasks	Authentic* Challenging* Integrative/Interdisciplinary*
Assessment	Performance-based* Generative Seamless and ongoing Equitable
Instructional Modes	Interactive* Generative
Learning Context	Collaborative* Knowledge building Empathetic
Grouping	Heterogeneous* Equitable Flexible
Teacher Roles	Facilitator* Guide Co-Learner/Co-Investigator
Student Roles	Explorer* Cognitive apprentice Teacher Producer

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* Shows indicators provides by Means and her colleagues (1993).

for each variable, combining the indicators given by Means and her colleagues and those given by us. In the next section, we develop analytic descriptors for technology and indicators for high performance technologies that promote engaged learning and instruction.

Emerging Consensus on Technology Performance

Looking at technology through the lens of learning, we developed six neutral variables of technology performance that are descriptive and analytic. These variables are (1) school access to diverse technologies and resources both beyond the school and within a given classroom; (2) operability; (3) location and direction of resources—whether the technology has a central source or has distributed resources; (4) capacity of the technology or program to engage students in challenging learning; (5) ease of use; (6) functionality, which is the capacity of the technology to prepare students for a diversity of technology functions.

What does high performance technology look like when we consider each of these variables? How can technology be designed to promote engaged learning? Again, as was the case with learning, this question could be answered in somewhat different ways by different technology specialists and researchers. In fact, there is now a burgeoning literature on design features of technology that promote meaningful learning and collaboration (e.g., Cognition and Technology Group at Vanderbilt, 1991a, 1992a; in press; Cunningham, 1991; Duffy & Jonassen, 1991; Hawkins & Collins, 1992; Knuth & Brush, 1990; Newman, 1992; Pea, 1992; Schank, 1990, 1991; Spiro, Feltovitch, Jacobson, & Coulson, 1991; Wilson & Tally, 1991).

Despite the diversity and richness of specific concepts in this literature, there is strong consensus in this research community that technology artifacts such as tools and technology-enhanced programs can be designed to promote engaged learning. Moreover, there are many features of technology and programs that continually recur in diverse contexts and/or have been developed over many years by a specific research group. Using this literature as a backdrop, we defined indicators within each of the six technology performances that would yield high performance (vs. low performance) <u>and</u> would promote engaged learning and reform instruction. Please note that in this component of our framework, there is necessarily a certain amount of overlap, redundancy, and interrelationships among indicators. For example, connectivity to the Internet implies distributed resources.

1. Indicators: Access. A technology or technology-enhanced program has high performance in terms of access when it has connectivity, ubiquity, and interconnectivity. *Connectivity* refers to the capability of technology to access rich resources within and beyond the school because it is connected to those resources. "Last-mile connections" from the school to a telecommunications source must be in place if schools are to access the wealth of free and low-cost resources on the information highway. *Ubiquity* means that computers, printers, media technologies, and other equipment must be everywhere within the district and school so that all teachers and students can access and use them as tools to solve problems, communicate, collaborate, and exchange data. This does not mean that every student must have a computer; that would be ideal. It does mean that having a computer or multimedia laboratory in every school is not ubiquitous because students and teachers have to go someplace and perhaps experience long delays to use the equipment. Under these conditions, users cannot use the equipment as an everyday tool. What is needed is to network a critical mass of computers and other equipment, especially printers, throughout the school so that teachers and students can use them when they need them. *Interactivity* refers to the interaction that occurs when students and teachers actually communicate and collaborate in diverse ways (exchanging data in different formats, and publishing).

In addition to these three features, there is the issue of <u>what</u> users access and <u>who</u> has access to the best and most extensive resources. A system can be connected and interactive but not all students are accessing the quality resources. For example, a system may have home-school connections but not to the local library system or the Internet. Or schools may have connections to the library system and the Internet, but only the students in the gifted classes or the magnet schools are really set up with instructions and training about how to use those connections effectively, while low-achieving students are working with programs focused on low-level objectives. Also, poor schools may not be well informed about the more powerful connections and programs, so they always get a busy signal or their software may be so poorly connected and configured that it is too cumbersome to use frequently. There has to be a powerful *design for equitable use* of the technology, program, or configuration to address these issues. That is, technology use in schools should be designed and implemented so that all students have access to rich and challenging learning opportunities and instruction that is interactive and generative. It is this design feature that promotes opportunities for engaged learning for all.

2. Indicators: Operability. A technology or program has maximum performance in terms of operability when it has *interoperability*. According to recent legislation (e.g., Congress of the United States, 1994), interoperability is the capacity "to easily exchange data with, and connect to, other hardware and software in order to provide the greatest access for all students." To achieve this, it is necessary to have *open architecture*. This feature allows users to access data using different (third party) hardware and software; it also allows users to modify the system, sometimes dramatically (e.g., the capability to add one's own template to a spreadsheet program). Open architecture means that software at major hardware/software outlets has "shrinkwrap availability"—a common metaphor in the field. Interoperability also requires *transparency* (moving from one format or program to another easily and unobtrusively). This means that users are essentially unaware of the procedures used by the hardware and software for changing programs and multitasking (allowing users to be working on several tasks at once within the same system).

Technologies or programs that have open architecture and transparency are likely to promote engaged learning because they allow the learner to spend maximal time and energy enjoying and using the resources they access, rather than spending the time and energy in the process of learning to use the technology and/or doing complex and time-consuming procedures to move from one program or format to another. Moreover, these capacities promote learning because they allow the user access to more resources, an issue we will discuss below in reference to other indicators.

3. Indicators: Organization of Resources. Indicators in this category pertain to questions such as, Where is the information/data stored? How are resources connected? How do new resources get into the system? Is the transmission asymmetrical (from one source to another) or symmetrical (two-way transmission capability)? Is information flow one way from a central source to others (asymmetrical) or two ways (symmetrical)? Who is in charge?

In some schools and technology programs (1) information is highly centralized, typically in mainframes or other centralized servers, (2) students may use "dumb terminals," which have few capabilities, and/or (3) users can share files from other users within the system—within the same building or district. In such systems, most of the information is asymmetrical; it flows in one direction—from the system to the users. The system operator is in charge of what information and resources are entered into the system, when it is entered and distributed to others, and so on. An example is a distance education course that is provided by a university teacher whose role includes such things as providing most of the information, coordinating who asks and answers questions, and defining the student assignments and products. Another example is what we call an "electronic basal," which provides highly structured information, instruction, and assessments for students; makes decisions about which unit or module to work through next; and controls when and how the student responds to the information presented by the system.

Centralized systems are likely to inhibit learning to the extent that they employ the transfer model of learning and instruction. This model assumes that the central source "contains" most of the important information to be learned and that it is the job of the student to transfer the information from the central source to the user's location and "learn" it. Such systems may be powerful technologies that offer rich resources such as a multimedia encyclopedia, options to use an array of media technologies including video, and efficient management systems for assessment and record keeping. From this perspective, central source systems would be high performance. However, the high performance and power may be very limited, relative to distributed systems. Further, learning may not be very engaged because the model of learning is essentially a one-way transmission model and the objectives are likely to be low level, focusing on basic skills.

In contrast to these centralized and relatively closed resource systems, *distributed resources* are organized very differently (see Newman, 1992). Specifically, they assume (1) that intelligence does not reside in individuals but is socially constructed through collaborative efforts and (2) that the resources that shape and enable activities (to build socially constructed knowledge) are distributed across people, environments, and situations (Pea, 1993, p. 50). This feature allows users to access resources (1) from anywhere in a local system (Local Area Networks, LANs) and (2) from anywhere external to the system such as from the Internet (Wide Area Networks, WANs, or world wide web, WWW). Thus, systems that provide only a LAN are considerably more limited than systems providing

WANs and WWWs. It is clear that these networked, open systems are designed for two-way transmissions and *user contributions* such that the information is reusable. That is, information, products, and services can be contributed to the system from multiple sources such that large numbers of users can share common data sets or problem spaces. Such systems have distributed logic in that much of the logic of preparing documents and artifacts for the systems resides in the user who must comprehend and build the linkages within and among documents or data sets. Thus, users must understand the logic of how the resources are distributed. They are in control of when they make contributions and what those contributions are.

Moreover, such systems typically involve components or tools that are *designed for collaborative projects* and co-investigations. For example, on-line conferences and bulletin boards with asynchronous communications capability, access to remote files and joint products, and the capability to communicate synchronously with two or more computers accessing the same file at the same time—all these promote collaboration. Other examples include programs that help groups form consensus, brainstorm, outline, develop plans, schedule meetings, monitor programs on group objectives, and develop joint products. Such systems inherently afford the user the opportunity to examine data, problems, and decisions from multiple perspectives. All of these capabilities facilitate developing knowledge-building communities in which many users converse to develop common understandings, products, and services (see Pea, 1992; Scardamalia & Bereiter, 1992).

Major technical issues that have arisen with regard to distributed resources are, How powerful is the system? Can it communicate in diverse media (audio, video, print, and virtual reality)? How many users can use the same resource without delays and loss of quality to the data? How many tools can the system support for simultaneous use?

4. Indicators: Design Features for Engaged Learning. High performance technologies and technology-enhanced programs can be designed or set up locally to promote engaged learning. One such design feature is for the software itself to **provide challenging tasks, opportunities, and experiences** or access to those things. This refers to the system's capacity (a) to provide complex problems and cases, links to challenging curricula, and unique repositories from museums and libraries; opportunities to examine contrasting events or data sets; (b) to access experts, peers, community members, and/or other learners who can guide, mentor, tutor, mediate, broker, share, inform, and involve users in productive and meaningful ways; (c) to use the richest media resources—images, audio, video, 3-D, virtual reality—for data manipulation and for presentations; and (d) to provide tools for interactive browsing, searching, and authoring.

A second design feature is for the software to allow students to **learn by doing**, to situate the learning in captivating and challenging activities. Thus, tools such as authentic goals-based scenarios, problem-based learning, problems anchored or embedded in challenging narrative situations, and simulations would provide the user with experiences to develop expertise using real-world problems and resources. Such tools allow the user to plan, reflect, make decisions, experience the consequences of actions, change directions, and examine alternative solutions and assumptions.

A third indicator of designs for learning is the extent to which the system *provides guided participation* (Collins, Brown, & Holum, 1991; Merrill, et al, 1993; Pea, 1993). This is the capacity for such software features such as Socratic questioning, intelligent tutoring, diagnosis and guided analysis of errors, and adaptation of the system to respond to student responses, to customize the content to particular interests or learning styles. Another way to guide participation is to make explicit what is typically implicit (e.g., Edelson, et al., 1994; Pea, Edelson, & Gomez, 1994). To explain: Thinking is an activity that is often covert and/or full of implicit references and assumptions. There are various ways that tools can help students see how practicing professionals and others think. One way is to build intelligent tools, such as wizards (that help users work through a set of complex procedures), embedded questions or prompts, and coaches. These tools provide the learner with opportunities to anticipate problems, subsequent events, and others' thoughts such as in cartoon bubbles. Another way is to provide powerful ways for students to have file sharing so that students can make their own thinking more explicit in their writing and they can see how others read and respond to their work.

Another design indicator to promote engaged learning is the capacity of the system to provide information that is *just in time and just enough*. Hypertext, for example, provides for nonlinear learning and thinking and multiple points of entry so that the user can quickly access specified chunks of information. Hypertext, and other tools, may also be designed for users with different levels of expertise (introductory and advanced) and for information access, help commands, and user control. Finally, high performance on this indicator means designing a system so that persons who have little time and/or immediate, pressing problems have easy access to simplified and useful information, while persons with time for reflection and exploration have access to more complex and rich information.

5. Indicators: Ease of Use. High performance with regard to ease of use refers to several features. *User friendliness and effective help* opportunities that are truly informative, well organized, and context specific are essential. *Speed* of processing and operations with feedback provided for all delays make a system easier to use than a system that is slow and does not provide such feedback. *User control* means that the user can access tools, information resources, experiences, and opportunities on demand and use them to solve problems, make decisions, and create products. This design feature promotes intrinsic motivation and exploration as well as being responsible for learning. *Training and support* to use the technology, as well as to apply it to solve problems, create products, and so on, are vital for all users. Further, training and support should be available both locally and from remote locations; and it should provide quality training and support resources.

These ease-of-use features help the learner <u>access</u> the resources and learning experiences offered by the system. Whether the learning that results is engaged or passive depends on the design and other features of the technology.

6. Indicator: Functionality. One indicator of high functionality is opportunities for students to *use media technologies* such as color printers, video cameras and video editing equipment, facsimile machines, audio recording and editing, and various graphics. A second indicator of high functionality refers to the capacity of the technology or technology-enhanced program to prepare learners to *use the diversity of tools that are basic to learning and working in the 21st century*. This would include teaching students how to use such basic or *generic tools* as databases, spreadsheets, and word processing that are needed for learning and for use in the workplace and community. High functionality would also mean providing students with options to learn how to use *context-specific technologies* such as radiology in medicine and biology, or tools such as sonar for oceanographic research.

Third, it is important that students develop *programming and authoring skills*, not as an end it itself but as a means to doing meaningful work in school, at home, and in the community. Moreover, such skills should be taught more in the vein of learning how to learn because specific programming languages and authoring programs are being developed continually, and students need to develop criteria for selecting them as well as some facility to learn them.

A fourth indicator is the capacity of the software to *develop skills related to project design and implementation* such as setting goals and benchmarks, creating and monitoring budgets, conducting research and development, preparing analyses and presentations, developing dissemination skills, and marketing. All of these activities, which are increasingly widespread in project-centered schools, the workplace, and the community, may be accomplished using technology. Developing such skills also means having a good working knowledge of what the Internet is all about and how to navigate it for resources that are needed for projects. Thus, students need to learn about the Internet not as a replacement for programming language taught as an end in itself but as a resource for a project or tool.

A fifth indicator of functionality is the extent to which a technology or technology program *prepares students to use tools that create new tools*. This refers to opportunities to use tools such as wizards and Mosaic as well as opportunities to learn programming and authoring skills to create new programs and tools for others to use. This contrasts sharply with traditional approaches to technology which might, for example, teach students outmoded programming languages as an end in itself.

Table 3 on the following page summarizes the variables of technology performance and the indicators for high technology performance. It is important to note from the outset that not all of these categories apply to all technologies. For example, it is possible to have high performance tools that promote engaged learning and educational reform but which may or may not have interoperability, connectivity to other resources, and distributed resources.

TABLE 3

HIGH PERFORMANCE TECHNOLOGY AND ENGAGED LEARNING

Variables of Technology Performance	Indicators for High Technology Performance -> Engaged Learning
Access	Connectivity Ubiquity Interactivity Design for equitable use
Operability	Interoperability Open architecture Transparency
Resource Organization	Distributed resources and logic/intelligence User contributions Design for collaborative projects
Engagement	Opportunities for challenging tasks and experiences Opportunities to learn by doing Guided participation and intelligent tutoring Information just in time and just enough
Ease of Use	Effective helps User friendly User control Training and support Speed
Functionality	Use of multimedia technologies Use of generic tools Use of context-specific (work-specific) tools Programming/authoring skills Design and project implementation skills Use of tools that are used to make tools/programs

Learning and Technology Interactions and School-Based Policy

Now that we have rich indicators for engaged learning and high performance technologies, we can return to the argument made by Means and her colleagues (1993). Specifically, *technologies and technology-enhanced programs should be measured by the extent to which they support engaged learning and educational reform.* There are two ways that one could analyze the intersection between learning and technology. First, one could develop tools to score the indicators systematically in various ways. Second, one could apply the concepts of engaged learning and high performance technologies to examine the intersection of learning and technology in broad terms. Each of these approaches is described below.

Tools for Schools and Others. We have developed a series of tools that link learning and technology to local school policies. These tools may be used by schools and others to serve various functions. They could be used to plan and design a program, describe and improve an existing one, or compare two or more programs under consideration for purchase. They could also be used by researchers, policymakers, evaluators, teacher educators and their students, agencies developing standards for similar purposes, and commercial vendors.

The tools we developed require the user to reflect on each indicator for learning and technology, to provide a score for each one, and to plot the scores in various ways. Specifically, the scoring system we have developed allows users to indicate the level of involvement or development with regard to that indicator at the practice level and at the policy level. To elaborate what is meant by practice and policy, consider the following example comparing two hypothetical schools and their use of authentic tasks.

> Example: School A has just begun developing such tasks through a very powerful technology program they are piloting (learning practice). They have implemented the program as part of their new mission to become aligned with the learning and technology needs of the 21st century (learning and technology policy). In contrast, many teachers at school B have been developing authentic tasks through the school's assessment program (learning policy), and this development is a major strength. School B has almost no technology in place (technology practice), but it has become a major agenda in their school improvement plan (technology policy).

Tables 4, 5, and 6 in Appendix B are tools that others can use to design, describe, and evaluate various technologies and technology-enhanced programs or curricula. Table 4 allows users to identify their **Current Realities** in terms of engaged learning and high performance technologies in two dimensions. First, users identify which of the indicators they have in place in classrooms now and to what degree. Then, they identify which of the indicators they value to the extent that they are incorporated in some way into a specific shared document or work, such as a mission statement, curriculum framework, strategic plan, design for a preferred future, assessment system, professional program, and the like. The combined scores then reflect current realities at the classroom level and at the policy level for engaged learning and high performance technologies. Users plot the intersection of Current Realities for Engaged Learning and Current Realities for High Technology Performance on Table 6, marking it with dotted lines.

Table 5 allows users to reflect on **Future Goals** for learning and technology using the information from Tables 4 and 6. Then they decide where they want to invest additional resources. For example, if user A has developed very high performance technologies but has limited capacities for engaged learning, then he or she may want to invest more heavily in developing capacities for engaged learning. Suppose, however, that a school has strong values/policies for engaged learning, but not a lot of indicators in place just now, and not a lot going for them in technology—either in the classroom or in policy. This school might want to look at the possibility of developing school policies on technology that can interact with the policies on learning and develop the capacity for engaged learning using technology. A different scenario might be that a school is highly developed in terms of learning capacities in the classroom and policies but has not become very involved in technology. Such a school might use the tools here to strengthen their policies on learning and let these policies and classroom capacities drive decisions and developments for technology. Reflecting in this way, users can use Table 5 as a design tool to generate new school-level policies and capacities for the Future Goals. Then these Future Goals can be plotted on Table 6 using a solid line. Thus, Tables 5 and 6 serve as tools for planning, design, and evaluation.

Tables 7 and 8 in Appendix C were developed to assist schools and policymakers in comparing two technologies or two technology-enhanced programs. These tables allow the user to mark all of the indicators for learning and technology respectively for both programs. Table 8 may be used to plot the two programs and see the differences graphically.

Technologies: Their Capacities, Designs, and Uses in Schools. In the next section, we examine the intersection of learning, technology, and policy in general terms. This analysis assumes that learning is an interaction of the technology capacities as well as its design and the uses of the technology in the learning environment. A technology can be high performance or low performance, but not be used effectively to maximize engaged learning. Our intent is threefold: (a) to categorize how the technology is typically used in schools; (b) to consider how its design and/or uses in school could be configured to move more toward very engaged learning and high performance (category A in Table 1); and (c) to examine state and national policy implications of this analysis.

In this examination, we will use the broad categories and trajectories presented in Table 1 that describe engaged learning and high performance technologies. We will also refer to the 26 learning indicators in Table 2 and the 25 indicators in Table 3 where appropriate, but our task at this time is not to analyze e-mail, computer-based approaches, and distance education and systematically work through each indicator for each approach. The intent here is first to generate a general idea of how each type of technology could be described when it is examined from the perspective of engaged learning and high performance technology. Then we will highlight some exemplary approaches/programs in each technology area.

1. **E-mail.** E-mail by itself is an inherently low-performance technology because it has only one function—to communicate. Therefore, issues of access, operability, resource distribution, and many of the design for learning features really do not apply. However, e-mail can be used effectively in schools to provide access to rich learning experiences, such as communicating with a tutor or mentor, and to promote collaborative work. E-mail inherently involves some degree of interactivity and exploration, but some interactions and explorations are more powerful than others. When students use e-mail to write informally to pen pals in another state, this is a good beginning. Some interesting and perhaps even powerful learning experiences may result, but they are episodic and unplanned. Teachers could use the same e-mail system to explore deeply complex cultural and linguistic issues or to solve problems with distant peers over a sustained period of time (e.g., Kidsnet, 1991); to communicate with practicing professionals and community members; and/or to conduct collaborative projects that will yield sustained, engaged learning and collaboration for challenging academic objectives.

2. **Computer-driven software and approaches.** Similarly, computer-driven software and approaches must be considered as an interaction of the technology design and the learning context or purpose. Computer-based instruction (CBI) used for drill and practice on traditional objectives is passive learning and technology. For example, Means and her colleagues (1993) argue that CBI focuses on teachers transmitting information to students, so that students are passive rather than active learners. They add that learning is divided into discrete content areas that require only "simple" responses from students, and that the focus is on drill and practice (see also Rockman, 1991). Additionally, Means, et al., raise equity issues: "Students at risk of academic failure—often seen as lacking in basic skills and therefore unable to acquire advanced skills—become logical candidates for CBI drill-and-practice instruction. Recent research and thinking on the needs of disadvantaged students stress a different need . . . opportunities to acquire advanced thinking skills and . . . basic skills within the context of complex, meaningful problems." (See also Means, Chelemer, & Knapp, 1991, for an anthology on this topic.)

   However, there are numerous other computer-based technologies derived from artificial intelligence (AI) and research from cognitive science that promote engaged learning. Such systems are designed to help learners think through complex, authentic problems; take charge of their own learning; and/or develop products for teaching or use in the real world. Such systems may use integrated media to:

   - Provide sophisticated expert systems for learning very complex concepts and procedures

   - Help students develop advanced skills such as reasoning, summarizing, high level self-questioning, and reflection

   - Diagnose and reduce student errors as well as remediate specific learning problems

- Adjust or adapt the level and sequence of problems based on student performances; suggest directions for new learning

- Stimulate the use of emerging technologies and decision-making to address complex real-world problems and issues, thereby providing learning by doing and guided participation

Consider two tools developed by the Institute for the Learning Sciences at Northwestern University. *Sickle Cell Counselor*, for example, was developed in collaboration with the Museum of Science and Industry in Chicago. This high performance AI tool was designed for the informal learning that is characteristic of museum settings. Users, therefore, are all ages, and only those interested in finding out more about sickle cell anemia would stop and use this tool. The program allows users to access vitally important health information by asking experts, by conducting laboratory tests, by interacting with "patients," and by seeing the consequences of communications to the patients (see Bell, Bareiss, & Beckwith, 1994; Institute for the Learning Sciences, 1994; Schank, 1991). Although *Movie Reader* cannot adapt to the responses of students and has fewer high performance indicators, it is nonetheless a very useful tool that embeds critical comprehension questions for students in video texts and allows teachers to generate additional questions to improve comprehension (Holum & Beckwith, 1993). This tool helps students to be responsible for learning, think strategically, collaborate, and generate deeper comprehension, thereby energizing their learning. From the teacher's perspective, the tool has facilitation and some guiding functions, with elements of cognitive apprenticeship in that the tool essentially coaches the students.

Other tools assist teachers and principals in various functions. For instance, the Illinois State Board of Education (1994) developed software for school improvement planning in partnership with NCREL. This software allows schools to enter student outcome specifications and assessments as well as other school improvement reports that are correlated to statewide school improvement plans. This software also assists educators through the very complex task of developing learner outcomes and assessments that are linked to national standards and meet state standards. The tool also assists users to think through the process of gathering and analyzing data about the assessments; to determine the quality of the assessments and assessment data; and to report the results to the community and the state. This tool will aid both the policymakers in seeing the "big picture" for each school and the classroom teachers in using the data to improve curriculum and instruction.

Also at NCREL, Knuth and others are developing software for School Development Resource Systems. Each system has (1) a library component whereby users can access abstracts for a range of topics related to school restructuring to promote learning; (2) a video-based component for classroom teachers to view and analyze various dimensions of expert teachers teaching a whole lesson, using a powerful database of print materials that include lesson plans and articles as well as resource contacts; (3) a multimedia database using Mosaic that is designed to help users make decisions on critical issues.

Additionally, The Cognition and Technology Group at Vanderbilt University is developing tools for teachers in inservice and preservice contexts. One of the hallmarks of this research is the use of contrasting lessons on video discs, mostly in science and mathematics, to stimulate reflection among preservice students. However, Goldman and her colleagues found that it was very effective to have groups of students create their own integrated media presentations using pairs of contrasting mathematics lessons (Barron & Goldman, in press). Risko (1992) uses video-based cases to broaden preservice teachers' perspectives and expectations by having them explore multiple sources of information that influence teaching students with reading difficulties. (See also Means et al. (1993) for a discussion of additional tools to support other teacher functions.)

Increasingly, computer technologies will "read" and "think" like humans, providing Socratic dialogue, analysis of human thinking, and interactions that are capable of tracking and responding to complex lines of inquiry (Beck, 1994; Schank, 1990; Schank & Edelson, 1990; Kumar, Smith, Helgeson, & White, 1994). There is also the capacity that computers and integrated media have to promote opportunities for learners to take charge of their learning (Papert, 1993). In terms of evaluating computer-based technologies, this means that the evaluation must consider the intelligence or thinking the computer can perform as well as its purpose or use in achieving a given instructional and learner goal.

3. **Integrated Learning Systems.** Integrated Learning Systems (ILS) are very high performance technologies, but in terms of their capacity to promote engaged learning, typically they are essentially electronic basals using traditional tasks and assessments, student and teacher roles, and approaches to instruction. They are designed to provide lessons and assessments targeted to basic skills required by traditional school objectives. ILSs are popular in part because they provide lessons, extensive teacher manuals, and assessments that are definitely aligned with each other within the ILS (though they may or may not be well-aligned to the objectives of all such schools). Some programs are interdisciplinary and include multimedia encyclopedias. They also provide inservice training for the system and the content of the program, easy-to-use and time-saving management systems, and good support for technology. Computers may be linked in local area networks (LANs). The Jostens Basic Learning Systems is an example, and they produce numerous profiles of successful implementations, mostly showing gains on standardized tests (promotional literature).

   Contrast this use of high performance technology with other high performance technologies configured to network schools and communities in wide area networks (WANs). Consider, for example, collaborative projects designed to study and manipulate actual images from NASA and to communicate with practicing scientists using the

Internet. In such systems, the technology hardware and software are configured for access to authentic, generative, and challenging data; for learning by doing; sometimes for guided participation and intelligent tutoring; as well as for user contributions and user control. The second example reflects the high end of numerous indicators including authentic, challenging tasks; instruction that is interactive and deeply generative; learning contexts that involve knowledge building; and the characteristics of teacher and student roles that promote engaged learning. It is important to distinguish between ILS and more open systems because many schools that have ILS believe that because they are high performance technologies, they therefore provide engaged learning and access to very rich resources.

Newman (1992) has criticized the way that most schools organize local area networks (LANs), especially ILS. "Although networking technology has tremendous potential to support school restructuring, for the most part, it has been counter productive—or at best irrelevant—to any significant change" (p. 49). While most schools have the modems that would link them to other sources of information and educational resources, network technology in most schools is set up primarily to download instructional materials from a central repository to isolated classrooms. The problem here is not the LAN itself, but the way it is designed to provide learning.

The core of the problem, according to Newman, is that ILSs are configured to provide information from a central source using local area networks for communication within a school and between schools using that ILS. That is, local area networks (LANs) are not connected to wide area networks (WANs) and distributed resources that could provide a wealth of external resources as well as opportunities for active learning and communication. Newman contrasts this model of learning with descriptions of Earth Lab, which allows students and teachers to access school resources throughout the world and engages students across the school in such tasks as editing the school newspaper. This distributed system also helps teachers to collaborate to design integrated, multidisciplinary curricula. Students and teachers subscribe to such services as weather reports, electronic mail, and bibliographic retrieval.

At the same time, Means et al. (1993) recognize that there is an emerging trend for ILSs to offer schools the capability to access "third-party" software and therefore provide more instructional options. We are also aware of ILS companies that offer some opportunities for engaged learning by providing teachers with powerful multimedia production capabilities to create their own curricular models as well as curriculum development services. For example, a few ILSs are developing (1) networking outside the system, (2) more powerful instructional designs that focus on authentic tasks (in addition to their "low end" lessons addressed to basic skills), and (3) ongoing professional development support, including curriculum development services. One ILS actually owns four satellites that allow two-way video communications among schools and the ILS as well as video cameras for all schools. Users can create their own video demos, share them with others, seek advice from expert teachers at other schools, and contribute to the video resources of the system, making it self-renewing. This ILS also assists schools to create new curricular units.

So what is the bottom line on the value of CBI and ILSs? The critics are saying that closed system electronic models such as the typical CBI and ILS that support traditional learner goals, curriculum, instruction, and assessment are fundamentally not much improved over traditional, nontechnology instructional models. In particular, the new research on learning is saying that traditional models of learning and schooling are not adaptive to the needs of modern society; we need to develop new paradigms of learning for technology designs. What these critics of CBI and ILS are saying is that to the extent these technologies support traditional teaching learning, they are misaligned with educational reform and the needs of the 21st century.

4. **Distance education technologies.** Similar analyses may be made for the interaction of learning and traditional distance education technologies. *The majority of distance education courses still address traditional instructional goals.* Indeed, "as of the current moment, the primary technology used for K-12 learning distance programs is based on an instructional television model which has been around as early as the 1930s." (Westrum, 1994, p. 2). Specifically, this refers to the use of one-way video with two-way audio, two-way video and audio, or two-way audio and/or audio graphics. The major distance education providers for students and for professional development include the Public Broadcasting System (PBS); TY-IN Network in Webster, Texas; the Ohio-based Satellite Educational Resources Consortium (SERC); the Arts and Sciences Telecommunications Service of Oklahoma State University (AST/OSU); and 11 of the 13 Star Schools Projects, as well as the satellite-based Star Schools Projects. Additionally, many states such as South Carolina, Virginia, West Virginia, and Wisconsin have developed rich resources/courses for statewide access.

   There are numerous studies that demonstrate, according to Russell (1992), that regardless of the quality of the production or the specific technologies used, students learn equally well with each technology and learn as well as their on-campus, face-to-face counterparts (see also Shavelson, Webb, & Hotta, 1987). There are two crucial issues here. First, what have these traditional distance education models accomplished? These analyses indicate that such models have achieved two of their major objectives: many students would have no instruction or very limited instruction without them, and this instruction is generally recognized as being equivalent to the instruction in regular classrooms. This is particularly true for the many specialized and advanced placement courses that enable a large number of students to enter college, an opportunity not otherwise possible. Similarly, distance education technologies provide access to many collections of rare documents and artifacts otherwise not available to remote locations (Office of Technology Assessment, 1988; 1989).

   Second, there are issues related to the idea of making distance education technologies more capable and more powerful, which would of course make them more expensive.

Russell (1992), for example, sees this as a problem. He asks why we should invest in more expensive technologies if less expensive technologies can accomplish the same goal?

We propose that this is the wrong question. What is the value of developing or supporting inexpensive or expensive technologies if they do not promote engaged learning? This is true whether the program provides a rare collection or instruction to rural schools that would otherwise not be possible. What is critical in the next generation of distance education paradigms is developing and supporting the technologies and models of instruction so that learning is interactive and generative; learning contexts are more focused on knowledge building; students are engaged in authentic, challenging tasks and have more control over their learning; teachers serve as facilitators, guides, and co-investigators; and schools may access distributed resources the world over. In fact, both the providers and the models are evolving toward these ends. Specifically:

- *Some traditional distance education providers are giving more priority to recent research on learning and educational reform.* Thompson, Simonson, and Hargrave (1994), for example, summarizes literature and presentations from a conference of providers. Factors examined included cognitive and affective aspects of learning, collaborative learning formats, distance education as a system involving many subsystems, and distance education in the context of school restructuring.
- *More distance education programs are using interactive and networked designs.* These designs utilize as part of the instruction computers, telephones, video by telephone, facsimiles, audiographics, and other technologies. Particularly exciting are opportunities for students and teachers to take expeditions electronically such as the JASON series. JASON is the acronym for a portfolio of satellite-based projects that follow the scientific activities of the world-renowned oceanographer and archeologist, Robert Ballard. He takes cameras into oceans, caves, rain forests, coral reefs, and the Mayan ruins of Belize. Students and teachers may communicate directly with him, his scientific teams, and other project participants via video teleconferences and computers. The JASON Foundation provides bulletin boards, software to download text files and data from project sites, and instructional materials that provide data synthesized by the scientists, challenging problems, biographical information about the Argonauts, and information about procedures for using the various technology components. PBS has also used many of these features in some of its distance education programs. Moreover, some of the satellite-based Star Schools projects and other distance learning providers are also using computer networks, more collaborative learning, and authentic tasks as well.

5. **Distance Learning Using the Internet.** Increasingly, we are beginning to move from a focus on distance education programs and technologies to distance learning (Karim, 1994). In part this is because promoters of engaged learning are asking what distance education technologies facilitate engaged learning. In part this movement is emerging

from the trend to understand information and data as resources, not just programs, spurred on greatly by the development of the National Information Infrastructure (NII) and the concept of using *the Internet as a major vehicle for distance learning at all levels*. Indeed, NII was designed to make "the best schools, teachers, and courses . . . available to all students, without regard to gender, distance, resources, or disability" (Gore, 1994). This dream will be enhanced and accelerated by software such as Mosaic that has the capacity to transport video and voice images. The dream will also be realized by access to digital libraries that offer collections of art, historical papers, and other unique or rare items on demand, collections once available only by satellite, video, or actual visit.

To summarize, following Means and her colleagues (1993), we have argued that technology effectiveness should be defined in terms of the extent to which technologies and technology-enhanced programs support engaged learning and instructional reform. We then developed the idea of conceptualizing learning and technology as two intersecting continua (Table 1). Specifically, learning was conceptualized on a scale moving from passive to engaged. Technology performance was defined as moving from low to high. This intersection yielded four categories and four desirable trajectories.

To elaborate on this framework, we enhanced the framework for learning developed by Means and her colleagues by adding one indicator category: the vision of learning, making a total of eight analytic categories. We also added indicators in each variable category to enhance the framework (Table 2). Similarly, we defined six neutral, analytic variables or categories for describing technology performance. Then we developed various indicators within each category (Table 3). This enhanced framework, we believe, could provide a powerful matrix for developing tools and for analyzing particular technologies and programs in broad terms.

Local, State, and National Policy Issues

In order for schools and others to design and use technology effectively to promote engaged learning for all students, certain elements inside and outside of the classroom must be in place. Specifically, we have identified five sets of policy issues related to learning and technology performance that greatly affect a school's ability to employ technology in classrooms for the kinds of engaged learning experiences identified by us and by Means and her colleagues. These policy issues are a critical component of our framework. Unfortunately, these issues are currently being addressed by different policymakers at local, state, and national levels and are therefore uncoordinated. More alarming, in many cases these issues (e.g., the relationship between traditional distance learning providers and the Internet) are not being addressed deliberately and systemically by any group of policymakers.

The first policy issue concerns **equity, or the goal of universal participation**. Although there has been a commitment to a national infrastructure and universal participation at the national level, this commitment must be made and, for the most part, funded at the state level. And, as local control has often demonstrated, the final application of this ideal must be implemented at the local level and guided by local policymakers. Universal participation, as a policy goal, must mean that every student in every school will have access to and active involvement in an information highway that connects them with other students and to the world.

This issue raises questions about funding for specific contexts (e.g., urban and rural); specific populations of users (e.g., poor and minority, children with special needs); and specific states (e.g., those economically depressed). Policymakers will be asked to make decisions about designing and financing state and multistate technology infrastructures that anticipate the high performance technologies we have described above.

The equity issue also raises additional concerns about the host of internal problems that prevent schools from being able to participate, even if they have the technology. Some of the obstacles are a lack of (a) focus and time for quality, ongoing professional development for the technology training; (b) models for curriculum, instruction, and assessment that promote engaged learning and effective use of high performance technologies; and (c) school architecture that supports a community of learners, knowledge building, and multiple technology functions. This equity policy issue rests upon the belief that students now academically at risk can achieve to high standards and engage in challenging learning that uses high performance technologies; and therefore, they should have access to both engaged learning and high performance technology.

Providing **high quality technology access for all students to achieve high standards of academic excellence** is the second policy issue. Whereas the first policy issue focuses on access, connectivity, and interconnectivity, this concern focuses on standards for learning as they apply to technology—ensuring that students at risk have opportunities to use the technologies to complete challenging tasks. This issue, as it applies to technology, calls for high standards for all children. This means making a commitment to establish high standards for technology access and use for all students through specific policies and financing strategies. The literature cited in the next section suggests that students academically at risk can benefit from learning paradigms that present challenging learning tasks and opportunities to use high performance technologies. Indeed, it may turn out that technology use to promote engaged learning is a very powerful vehicle for students at risk.

Major barriers exist, however, to implementing such policies at the local level. They are: (1) local assessments that focus on low level and conventional objectives; (2) technology initiatives fragmented (separated) from curriculum, instruction, and assessment; and (3) tracking systems that separate students and technology into low- and high-level applications. What is needed is (1) permission for schools to experiment on using technology as a tool for restructuring classrooms and the schools themselves; and (2) integrating policies that relate curriculum, instruction, assessment, and technology so that in practice schools curriculum, instruction, assessment, and technology are seamlessly integrated to support engaged learning.

Developing standards for technology performance and for the intersection of learning and technology so that all students have opportunities to reach the same high standards will be critical. A definition of technology literacy is needed that requires teaching students to use various technologies as tools to accomplish challenging tasks that empower their learning and are aligned to the workplace and community. This need has special implications for Goals 2000, ESEA, School Improvement, and school-to-work legislation, as well as the design and funding for the national information infrastructure. We also need national standards for what constitutes high performance technologies that promote learning.

The third set of policy issues surrounds the coordination of technology choices and uses from K-12 to postsecondary and to work. *The transition from school to work can be greatly strengthened by allowing students to become familiar with workplace technologies.* Employability is an important concern for all students, and experience using technology with high transfer to the community and workplace is important. The present strategy for purchasing and using technology in K-12, postsecondary, and school-to-work programs is not coordinated and involves many different policy players and many different configurations of technology and telecommunications. Private sector and public sector planning and K-16 planning could facilitate shared financing and improved articulation for school-to-work technology access and use.

The fourth policy issue surrounds **commitment to ongoing professional development** that prepares educators to implement the instructional and curricular strategies implied in the enhanced framework developed by us. This commitment involves time, financing, staffing, and powerful models based on recent research on learning, professional development, and technology use emerging from the cognitive science and related fields. Moreover, such a conceptualization must be based on the assumption stated in Goals 2000 and ESEA legislation (in progress) that all students can learn to the same high standards, which has important implications for building planning and classroom management as well as seamless curriculum, instruction, and assessment.

One final issue that must be noted for its absence in the literature on technology is the role of parents. While several programs involve parents or local community members, most do not. Not surprisingly, our experience in schools and SEAs suggests that many parents do not understand this major shift in technologies and programs—specifically, its importance for their children's experience in school and capability in the workplace. Historically, groups of parents across the nation have not supported initiatives focusing on teaching thinking. We believe that when this fear is coupled with technology, parents could feel very threatened if they are not brought into the partnerships (see description of Glenview in the Impact in Schools section following).

3. Learning, Educational Reform, and Technology

In this section, we describe four changes that are redefining educational reform. First, the strong national movement to open up the Internet to schools has created significant resources for curriculum, instruction, and assessment models for schools as well as for professional development. Second, this new set of content and service providers will have a major effect on the technologies and programs used in schools.

These forces may accelerate school restructuring considerably. Third, the nature of evidence needed to measure student achievement within this technology-enhanced environment will be significantly different from the focus on standardized tests used in traditional instruction. And, fourth, renewed interest and funding in school-to-work transition is linking workplace technologies with secondary and postsecondary educational experiences.

The National Information Infrastructure

The U.S. government has made a major commitment to develop the Internet as a globally networked technology infrastructure. The government is also committed to developing a National Information Infrastructure (NII) as the human, policy, and fiscal infrastructure that guides the development of the Internet infrastructure (see Ramirez & Bell, 1994, for a comprehensive treatment of the Internet, the NII, and education). The Internet was initially created to assist universities, government, and the military in communicating and collaborating. More recently, however, the developers of this infrastructure have set their sights on universal access. This includes not only opening up Internet resources to business and other adult users, but also to children in schools. We propose that the NII will fast become a profound force for ongoing professional development and systemic school restructuring, supported strongly by various agencies in the government including the National Science Foundation (NSF). NSF is issuing a major report on principles and goals of technology in education (Sabelli & Barrett, 1994) that will move the NII beyond universal access to participation and connectivity. Several recommendations from that document are worth quoting:

> Technology freely used will change who is in control of information within schools and classrooms.
>
> Technology can be, must be, used as a tool for inclusion instead of exclusion.
>
> Technology policy must promote the integration of educational technologies in school with the technologies outside of school. (As a corollary, they suggest that we must eliminate policies that prevent the development of a reasonable technical infrastructure (i.e., an infrastructure that has distributed resources, not single source providers.)

Develop appropriate technology goals and change those regulations that are barriers to achieving those goals.

The goals stated as "next steps" in this document are ambitious: First, define "full participation" by 1994 with expected outcomes. Second, provide electronic links to every school by 1996, every classroom by 1998, and networked student clusters within every classroom by 2000. The report urges that "the community at large must seek support from all sectors and design activities to implement these next steps."

New Education and Network Service Providers

According to the NSF report, one set of outcomes of this movement has to do with profound changes in what is delivered to schools and who is delivering it (i.e., who is in control of defining the content for students and professional development). We suspect that governmental and R&D agencies and electronic publishing will increasingly replace conventional textbook publishing as the next generation of content providers for schools.

We believe that there are critical differences between traditional and next-generation approaches. Collaboration and worldwide networking with schools will become the norm, co-development will become commonplace, and shelf life will be measured in months rather than years as products are developed and refined using the Internet.

Who are the new service providers? One category of providers is the array of government departments and agencies that are building the Internet and the NII. For example, recent policies of the U.S. government have permitted the release of huge repositories of free information and educational resources to schools through the Internet. These resources include NASA, the U.S. Weather Service, federal energy laboratories, various departments within the government such as labor and commerce, and diverse oceanographic and environmental agencies.

The activities offered by the providers in this category are quite varied. NASA, for example, has a model Classroom of the Future, massive databases of planetary images and other data available on the Internet, five regional teacher centers, curriculum activities for various projects, and opportunities for teachers to network with each other and NASA as a means of ongoing professional development. The JASON Foundation, supported by various government agencies, has similar activities. JASON V: Belize—Expedition Planet Earth, for example, which focuses on the rain forests in Belize in Central America, involved satellite-based delivery of on-line scientific activities, video teleconference to participating schools, bulletin boards for participants, curriculum materials, newsletters, student and teacher travel with the argonauts, and direct transmission of data sets to users. The federal energy laboratories also have diverse offerings to schools. In addition to releasing various data sets pertaining to the planets, weather, and energy, several of the energy laboratories (e.g., Brookhaven and Oak Ridge) are developing software to deliver 3-D images and virtual reality to schools using the Internet; many have school-based research projects; and some have special services for teachers such as the *Ask the Scientist* program at Argonne Laboratory.

A second category is agencies that serve schools in traditional ways. As a part of the government policies to develop the NII and the Internet, various initiatives are focusing on redirecting these agencies to serve schools as content and service providers for the Internet. Specifically, this involves the services and products of the regional educational laboratories (RELs), museums, libraries, zoos, and various agencies in the areas of health. Indeed, there is a high level movement to encourage informal consortia among these groups. Both the Smithsonian Institute in Washington, D.C., and the Chicago Museum of Science and Industry, for example, have extensive school-based projects and curriculum materials and both are developing consortia to develop ongoing projects and outreach to schools using the Internet. The Chicago Library System (all the library groups in Chicago) is working with the University of Illinois Library to develop two-way video desktop conferencing among users. NCREL has a strong commitment to this movement and is moving forward to connect its seven states through intermediate units and school districts and schools to R&D resources that are multimedia and delivered over the Internet directly to schools.

A third category of providers is the R&D community of universities and private nonprofit agencies devoted to improving education. We believe that schools will increasingly turn to the community as providers. We have identified several formal and informal consortia who have much to offer schools in terms of content and services based on recent research on learning. These groups also are very involved in shaping the policies, the national R&D agenda, and information highway system that will carry the content and services they have designed.

- One constellation of high end technology and learning developers is in the Boston and Cambridge area: Bolt, Beranek, & Newman, a primary developer of the national testbed concept described below; TERC, which focuses on technology resources and projects in mathematics and science; the Massachusetts Institute of Technology, which has done work with LOGO in various schools; and the old Bank Street technology group now at Education Development Center (EDC).

- Another constellation is the Cognition and Technology Group at Vanderbilt, which is developing an array of technologies and programs around the concept of instruction anchored in narrative formats and multimedia technology. This group is forming a consortium with the Bereiter and Scardamalia group at the Ontario Institute for Studies in Technology (OISE) working on CSILE (Computer Supported Intentional Learning Environments), and the Brown and Campione Group at Berkeley.

- A number of universities also provide major resources and support services to teachers, schools, or museums for a specific project or a group of projects: the School of Education and Social Policy and the Institute for the Learning Sciences at Northwestern University; the Image Processing for Teachers project at the University of Arizona; the

Common Knowledge Project for the Pittsburgh Public Schools developed by the University of Pittsburgh; and the many universities with strong technology-enhanced curricula for preservice teachers and/or technology research agendas such as the University of Michigan, Indiana University, and Ohio State University.

- The business community and nonprofit agencies are increasingly involved in providing schools with products and services that reflect recent research on learning and reform. These include curriculum materials developed at WASATCH, the national Apple network based in California, the Becoming a Problem Solver Series supported by SRI in San Diego, the Learning Circles initiative from AT&T, and the Buddy System at IBM.

A fourth set of providers is the community of electronic publishers; broadcasters; distance learning providers (see Westrum for summary of the research base, 1994); the video/film industry; telecommunications and computer companies; and the business community at large (the giants and small businesses) who will provide content, networking, and educational services. These providers will have increasing interest and control in what is available to schools, homes, and the R&D community.

What is to be provided? Networked schools can receive up-to-the-minute data from every sector of society around the globe, and they will be able to import a wealth of curriculum frameworks and materials to construct their own projects and curricula. They will receive ongoing professional development support based on research on learning. These schools can become part of a worldwide network of schools that collaborate with each other, research agencies, and practicing professionals to build knowledge communities. Many of the new data sets they will access will be in picture and video formats. A major part of this infrastructure is the development of digital libraries and museum learning environments that help students and teachers access, browse, manipulate, and interact with image and video data. Leaders of this movement to develop network and content services recognize the need to design new formats that avoid the linear and static data that often have been the norm for library and museum collections.

Different Kinds of Evidence for Technology Effectiveness

There is a growing skepticism about the use of standardized tests and traditional study designs such as pilot studies with control groups for measuring technology effectiveness. In place of these measures there is a growing focus on student performance on authentic tasks and projects in the context of real audiences.

One important new concept for technology and program evaluation is the notion of **national testbeds** developed largely by BBN (Bolt, Beranek, & Newman, 1992, 1993), TERC, and others to study technologies and programs that move toward universal access and participation in mathematics and science. According to Hunter (1993), a testbed is a combination of organizations, telecommunications networks, and educational innovations that involve ongoing collaborative inquiry in networked communities over long periods of time.

In testbeds, teachers, students, scientists, educational researchers, and administrators work together to develop expertise and to evaluate the costs and benefits of a given technology or program (or a multiplicity of them) as well as issues of scaling up to serve mass populations (See also, Bolt, Beranek & Newman, 1992).

In testbeds, attention to issues of technology effectiveness, cost effectiveness, and benefits for students and schools is ongoing through day-to-day communications and frequent interactive studies. Testbeds also involve an array of qualitative and quantitative measures. These measures include surveys of teachers and students, in-depth interviews, analyses of recorded communications and artifacts, and classroom observations. Student and teacher comparisons between testbed and nontestbed schools focus on documentation of changes in attitudes, beliefs, or behavior including use of tools and resources. Measures of student achievement make use of portfolios and project paths, contributions to the scientific or literary communities, and locally developed assessments. Standardized tests, such as the individual and group tests used in California, may also be used if they measure specific reform goals. The testbed analysis looks at changes in school organization, policy, programs, and practices. Currently, there is a wealth of formative data, but most testbeds are only just gathering or analyzing summative data so that they are unable to make strong recommendations about effects on student achievement at this time.

A major issue of technology effectiveness for all service providers is the "scale up" challenge. Most service providers from whom we have collected information say they currently serve about 500 schools. All such providers are making plans for serving much larger numbers. NCREL—which has the largest educational laboratory region—serves over 22 percent of the nation's children. Staff are considering ways to grapple with what we call the 20 percent problem—how to provide access to proven programs to 20 percent of the schools in the region. We think it is likely to include some combination of the Internet and next-generation distance education providers using satellite, cable, and other forms.

Impact in Schools. Several references have been made to the impact of technology on student achievement and school restructuring. Again, we note that much of the data below are preliminary but they are encouraging:

- *Greatly expanded information exchange capabilities.* This includes access to text, audio, and video, as well as search tools and bulletin boards for exchanging local and global resources. These capabilities include new technologies and tools such as World Wide Web, the Web Crawler, e-mail, gophers, distribution lists, and group mail reflectors.

- *New understanding about learning and understanding.* As students and teachers increasingly use the very complex information sources and tools provided on the Internet and directly by research agencies, they are developing new skills, knowledge, interests, and dispositions. We are referring here, for example, to the array of browsing, inquiry, and navigational skills for nonlinear learning in contexts. Further, these new learning environments have few familiar structures and markers as well as involve asynchronous communications, messy data, multiple perspectives and formats, distributed logic, entangled domains, and co-construction of knowledge or knowledge building. Such contexts stimulate new understandings of causation, intelligence and cognition, learning opportunities, learning environments, and achievement itself—for students and teachers.

- *Curriculum organized as projects involving sustained and complex co-investigations.* These projects exist across geographic and political boundaries and allow students to interact with practicing scientists and other professionals. Such projects actually offer students the opportunity to make contributions to science, literature, and other areas within local and global communities. Especially noteworthy are examples in the literature from TERC, BBN, and elsewhere in which academically at-risk students make significant contributions to the broader learning community, perhaps by creating multimedia and well-researched museum exhibits (e.g., Collins, Hawkins, & Carver, 1991; see below also).

- *Changes in student and teacher roles in the classroom.* Teachers and students are seen as contributors to knowledge, able to take charge not only of learning but also of creating and directing learning opportunities, and as co-investigators and citizens of the global learning community. Teachers and librarians are also seen as managers or brokers of resources. In addition, technology specialists are taking on a variety of roles that include expertise in linking to the R&D community.

- *Changes in the conceptualization and practice of professional development.* Professional development is ongoing. It is delivered in diverse media including e-mail, telephone, facsimile, video, audio and video conferencing, computer-driven software, satellite-based programs, and over the Internet—in many cases in network mediated contexts. Even print materials are trying to look and behave more interactively with innovative formats, customized structures, more hands on activities, and multimedia linkages. It is also delivered face-to-face at national, regional, state, and local centers as well as in schools, universities, and various other agencies that traditionally have not provided professional development experiences such as NASA, the JASON Foundation, museums, and libraries. Location for professional development delivery is now anywhere in the world.

  The persons designing and providing the professional development experiences include some new experts in the "real-world" including: practicing scientists, artists, telecommunications vendors, and authors. Agencies such as TERC, BBN, Argonne, AT&T, the Learning and Technology Group at Vanderbilt, now send out teachers on loan from schools serving as consultants and leaders, network support staff, and technology specialists. The transmission model has been replaced by mediating, coaching, sharing, listening, supporting, co-constructing, co-designing, co-investigating, co-producing, and co-presenting—all using technology. The processes of professional development experiences involve cycles of discussion, observing, modeling, reflecting, designing, trying out, revising, and refinement of strategies and activities over the years—using technology for input and for building knowledge with others. The traditional isolation of classroom teachers has been replaced by global learning communities and communities of practice. (e.g., Hunter, in press; Roupp, 1993).

Teacher roles outside the classroom are changing, too as the result of technology. As indicated above, teachers are increasingly consultants and technology specialists; policy decision makers for technology purchase, design, and use in schools; curriculum and software developers using multimedia, interns at educational agencies using, librarians, and navigators through the Internet. More often, teachers and school administrators are also key links between using technology at school and using it at home and in the community.

- *Accelerated curriculum and school restructuring to promote learning.* It has been widely assumed in both the research literature and practice that restructuring takes time, and that five years is not unreasonable for schoolwide restructuring. Numerous sources in the literature refer to using technology as a major strategy for school restructuring and for galvanizing teachers to act as change agents within the school. The primary source of this energy is the extraordinary motivation that many users derive from working on authentic tasks and collaborating with a broader learning community. Many schools are implementing interdisciplinary curricula and themes that center around the use of technologies—especially those involved in accessing the Internet. Moreover, student projects focusing on challenging authentic tasks often bring curriculum, instruction, and assessment that are not only aligned but essentially inseparable and seamless.

Thus, when technology has such a galvanizing effect, the time needed for curriculum and school restructuring may be reduced significantly. Goldberg and Fortunato (1994) estimate that these processes can be done in three years, starting from scratch (i.e., moving from a very limited emphasis and capability on technology to schoolwide use of technology to conduct projects).

An example from Glenview Public Schools in Illinois will illustrate how fast this process can be when schools do not start from scratch. Essentially, there were two technology initiatives. First, there was a major movement within the school district and community to network various groups and agencies using broadband cable. While elements of this networking were already in place prior to 1992, and various community members knew about these elements, concerted action began in 1992 and was the system place in the spring of 1994. The communications, technology, and overall plan for this process is described in detail by Mundt (1994).

During the school year 1992-1993, the district had separate initiatives for instruction and technology. For instruction, they were providing ongoing professional development for a thinking skills program that was to drive the agenda for curriculum, instruction, and professional development. In a separate but parallel initiative, the district had established a well-equipped computer lab in every school with enough computers for each student in the class to use a computer.

In the spring of 1993, the district hired a consulting group to evaluate the district's current use of technology and make recommendations. The group stated that the district's technology operation, organized in a single learning laboratory in each school, was impressive as a beginning. However, they maintained, if the teachers and students were to use technology as a tool, it must be accessible in every classroom. The group estimated costs to accomplish this. The recommendations were published in a letter mailed to every resident, and the district subsequently reallocated funds to support the recommendations over a 4- to 5-year period.

As part of the plan, in 1993-94 the Technology Director, James Flanagan, began to seed high quality technology programs in classrooms throughout the district so that a few teachers were linked to stellar technology projects. In the fall of the second year (September 1994), the district was to be divided into pods or trees. One tree was technology so that all classrooms in that tree would have very high performance technologies and various technology-enhanced programs that would yield sustained and engaged learning.

A major part of this plan was to distribute the research literature from each technology project and other technology research to teachers and district staff, involve them in powerful projects, such as Global Schoolhouse and CoVis, and provide ongoing staff development. These projects were so successful that by April 1994 the technology plan was the driver of curriculum and school organization at the district level with very high levels of enthusiasm from students and teachers, according to district staff. That is, the learning paradigms underlying these programs emphasizing challenging, authentic tasks and collaboration were so effective and attractive that these concepts began to extend and redirect curriculum, instruction, student and teacher roles, and assessment. Teachers then began integrating the thinking skills into the projects so that the technology initiative and the thinking skills program became integrated conceptually. Thus, the learning research reflected in the technology initiative became the driver for the instructional model for the district.

Another example of very accelerated school restructuring concerns a massive effort to demonstrate the effects of technology on selected schools abroad in the Department of Defense (DOD) for a major international demonstration of networked technologies (Goldberg & Fortunato, 1994). The initiative involved radically restructuring these DOD schools for large scale, collaborative projects. One of the projects involved doing something that had never been done before: creating an original orchestral arrangement using the Internet such that the different instruments would be played in different locations around the globe. Overcoming many technical obstacles, resistance to school restructuring, and the constraints of working at a distance through technology, the project actually failed in two attempts to rehearse the piece of music so that when it was played for the Vice President, no one was certain it would work. However, after some delay, it did.

- *Changes in student achievement.* There are a number of technology-enhanced curricula that have well-documented results in terms of improving student achievement even using standardized measures. Pogrow's (1990) HOTS Program and The Jasper Woodbury Series, developed by the Cognition and Technology Group at Vanderbilt (1992b), for example, are perhaps the most well-documented and both are effective with students at risk. Numerous other programs have very promising data from project documentation, surveys, and classroom observations regarding students at risk. Other studies contain many references to improved understanding of concepts, more engagement in active learning, preference for more difficult questions and challenging tasks, more student leadership, and more engagement in authentic tasks that provide real products, services, and outcomes for actual audiences. Especially rich illustrations come from the TERC testbed (e.g., Weir, 1993).

Some of the stories/cases from this literature are very dramatic. In one study, learning disabled students were required to use integrated multimedia technologies to make presentations. Teachers who initially did not believe that students could complete the task were awed and personally moved at the quality of the presentations; they realized that these students were able to tackle considerably more difficult tasks than previously assumed (Cognition and Technology Group at Vanderbilt, 1993; Hasselbring, et al., 1994). In another example, low-achieving students in Rochester developed an exhibit on the city that was displayed in the local museum (Collins, Hawkins, & Carver, 1991).

Another example comes from Whittier Elementary School in Chicago. Working with NCREL to implement instruction based on authentic tasks, the school took a considerable risk to abandon a traditional summer school curriculum and implement one based on authentic tasks including using technology and desktop publishing to create and publish a school newspaper. Teachers who had been highly skeptical all agreed that it was the most successful summer school in the history of that school and was instrumental in restructuring the regular curriculum during the school year. Since then, the school has rapidly implemented networked technologies and projects, including several international ones.

Two final examples of student achievement illustrate what can happen when students engage in authentic tasks that actually change their roles and relationships. One success story is taken from the Image Processing for Teachers project at the University of Arizona. This project provides students at various grade levels with large sets of planetary and weather images from NASA and other sources as well as actual (messy) data such as x-rays and archeology findings from various research laboratories. The students' role is to clarify and analyze this data, using an array of image processing tools from NIH Imaging. (This is the same software from the Internet used by many scientists working with images.)

During this process, students and teachers regularly communicate with project staff who are trained content specialists. In the process of working with these images, students and teachers can, for example, predict with 80 per cent accuracy certain lung diseases, piece together fragments of ancient pottery, conduct forensic research, generate new image representations from a given image including three dimensional ones, clarify photographs full of static or discoloration. Moreover, project staff have worked to provide historically interesting data such as actual images from photographs taken from space, slides of tissue used in research on the effects of alcohol on liver, and images of the brain in research just being conducted on the effects of drugs. This project has spread rapidly across the nation, sometimes involving a whole school after only one teacher is trained and can be done with one computer per classroom. There are many stories of high-level achievement among students at risk and their teachers including presentations of findings at professional conferences.

The second example involves middle grade students at Pease Elementary School in San Antonio, Texas, who were taking air samples using an air pump designed by TERC (Berenfeld, 1993). Because the students were not permitted to go out into the environment, they measured the air in the classroom, found too much CO_2, and concluded that it was an air pollution problem. The school called the local Environmental Protection Agency. Officials visited to measure the quality of air at the school using equipment very similar to that used in the classroom and confirmed the students' measurements. Both sets of findings were communicated on the Internet. Students from a school in South Carolina commented that they had compared air samples in regular and mobile classrooms, expecting the latter to be worse, but found the opposite. Apparently the opening of doors in the mobile units brought fresh air into those classrooms. According to Pea (1992), "the pedagogical goal is to have students better able to engage in appropriate conversations about the conceptual content they are investigating." As part of the conversations among the participating schools and practicing scientists, the students were able to reason that the problem was ventilation, not pollution. More important, their conversations with local officials and with scientists gave them new roles and ways of thinking about themselves as learners and researchers.

- *Changes in the definition of learning community.* We used to think of school as a place where students learn. Then we understood that schools and local communities had to function together to help students learn, so that there was a broader learning community. Now we think of national school networks connected electronically such as those sponsored by BBN (1992) and the Cognition and Technology Group at Vanderbilt (in press) as well as global ones such as the Global Lab international network at TERC (Berenfeld, 1993).

All this is not to say that implementing technology is easy. Certainly, it has been clear throughout this paper that too many instances of technology implementation are ineffective because the technologies and programs did not promote engaged learning and/or did not provide ongoing professional development. However, there are other problems such as the cost of technology; lack of information about where to go to find effective help in purchasing and implementing technology; shortage of experienced professional development staff; and barriers within schools such as resistance to change, fear of technology, and lack of time and funds for teachers to develop new skills (e.g., Office of Technology Assessment, 1993; 1989; 1988). The reality is that many teachers and school administrators have never heard of the Internet and have little to do with technology.

Technology and School-to-Work Initiatives

The literature provides a number of options on how technology can help align student skills with those needed in the broader community and workplace. Technology may be used to support most of the basic workplace skills, such as negotiation, collaboration, and knowledge of systems. By extending our efforts, we could provide students with many of the basic workplace technologies such as word processing, use of multimedia formats for presentations, and spreadsheets. Of more serious concern is how to give students access to some of the very expensive workplace technologies that are context-specific, such as imaging technologies (e.g., CAT scans) used in the medical and biological sciences and large printing presses. Imaging will be increasingly important to all citizens in the 21st century because of its superior capability to communicate information, especially technical information. The development of imaging technology devices and technologies such as photography, motion pictures and video, television, and computer workstations has facilitated the production and communication of knowledge. Images have become essential to science, medicine, industry, education, psychology, and culture generally (Beck, 1992, 1994). It is vital for students, teachers, schools, and community members to understand the basic principles of this technology and the scope of its uses in various fields such as radiology.

Some mergers of school-to-work transition initiatives would promote the use of workplace technologies by students. For example, museum exhibits and specially designed work stations for schools allow students to have sustained learning experiences with high performance technologies that promote engaged learning. We also found two emerging models of teaching and learning that support quality learning experiences and address the new focus on school-to-work transition: (1) cognitive apprenticeship and (2) the idea of knowledge-building communities. To explain: These models emerge from research on learning, but they have a natural conceptual affinity for school-to-work issues because both seek to engage learners and communities in social relationships that are so critical in the workplace.

Cognitive apprenticeship, for example, is built on the (occupational) apprenticeship idea that uses the teacher as coach and mentor. Thus, the elementary or high school student in the role of cognitive apprentice is able to have a relationship with his/her teacher as coach and mentor that is metaphorically like the occupational apprenticeship. The knowledge-building model in eduction was designed in part to simulate how members of the learning community each provide multiple perspectives on a problem—in the world of work, in community problem solving, and in R&D collaboratives.

4. Regionality as a Strategy for Designing and Implementing an Effective Technology/Learning Interface

Universal Access and Technology Growth as Problems for Education

There is a need to develop both a human and technology infrastructure that provides content and services to K-12 education. Decisions with profound consequences are being made about how various technologies will be integrated into the home, business, and entertainment markets within and across the United States. Education as a public institution needs to be at the table with business, the telecommunications industry, the power companies, the military, and others when vital issues of access to information are decided. Many of these industries, such as telecommunications and power, work on a regional service base. We propose that it may be to the advantage of education to explore multistate cooperation to take full advantage of vendor regional delivery capacity, economies of scale, and shared planning and implementation resources.

Technologies are expected to reduce greatly inequities in many contexts because in theory they can provide universal access to information. That is, since everyone should have equal access, everyone should have equal opportunity to learn. As noted above, the government and others are moving from the concept of universal access to the assumption of universal participation. However, too many poor schools face obstacles that hinder and/or preclude their access to these learning opportunities. These obstacles include (1) lack of funds to buy the needed technology, (2) curricula and assessment programs that focus on low level skills even when technology is applied, (3) school faculty who need to develop the instructional strategies to use the information that they can access through the technology, and (4) bureaucracies that keep communication and development from moving beyond the walls of the school into business and community sectors.

Goals 2000 and the technology legislation in progress may alleviate some of the funding crisis and go some distance toward assisting poor schools in providing ongoing professional development. Nevertheless, it is quite possible that richer schools, which are able to access and use information and research resources, will get "information richer" while poor schools, by comparison, will become significantly "information poorer." As the richer schools develop greater expertise, they also develop a much higher capacity to develop themselves and their related agencies. Poor schools are often preoccupied with curricula addressed to low level standards and objectives. When more schools are given permission and incentives to develop innovative curricula aimed at high standards, it will be much easier for them to use their funds to purchase technologies configured to support new learning paradigms.

Four related problems also exist. First, many researchers have cited the limitations of the factory model of schooling in curriculum, instruction, and assessment. What is mentioned less often—if at all—is that top-down management and high volume have been *the* economy of public education as an institution. This also happens to be true in many businesses, according to Reich (1991). Textbooks and equipment, supplies, and consulting, information, and management services all are purchased and distributed according to hierarchical, centralized structures—structures that are out of alignment with today's needs in both education and business. The new technology-driven organization and delivery of information, services, and equipment can and must address this issue.

Second, systemic reform in the cities has been long challenged by school funding formulae that depend on residential property taxes. If education is to change, the tax and funding structures of schooling must be part of that change. Ironically, the funding crisis in public education has given birth to new public/private sector ventures and some of these ventures are bringing new funding for technological initiatives. Following are three examples: (1) the plan for the Edison Project, which will provide and support high performance technologies that are oriented to sustained learning and management (Edison, 1993); (2) the Television Curriculum Network described in *Newsweek* (Toch, 1994, p. 69) developed by Eric Jones who was instrumental in developing Channel One; and (3) Whittie's Channel One, which delivers news supported by advertisements from commercial vendors. Television Curriculum Network—unlike Channel One, which does not integrate the brief video news modules into the curriculum, will provide video segments that are linked to various standards and curricular objectives and so will be integrated.

Third, the scale up challenge will probably require the formation of new organizations and consortia. It seems unlikely that any one institution or agency will be able to provide very large-scale technology services to schools and still maintain quality services. In part, this is because no one technology should dominate large efforts, and because large efforts likely will combine technologies—such as linking telephones and televisions, which many schools have—with computer-based approaches and technologies from industry. We believe that some creative approaches to conceptualizing the scaling up problem are required. An approach to this problem is discussed below.

Fourth, there are broader economic reasons to think about strategies that go beyond a given city or state. Ramirez and Bell (1994) for example, have argued that the purchasing power of a multistate agency is far greater than that of a single state. Ohio State Senator Horn (1993) has argued that regional university consortia would provide the academic resources needed to develop the technology expertise to support the aerospace industry. He would also join industries in such a region to commercialize the aerospace technology for use in the private sector, and Gooler (1994; NCREL Policy Brief on Technology Infrastructure, 1994) has argued that multistate or regional consortia would be powerful enough economically and politically to bring education to the policymaking table for decisions about technology and telecommunications.

There are many who think (1) that the crisis in education is urgent especially regarding issues of equity, technology, and the skills needed for the 21st century; (2) that there are important opportunities to restructure schools with major initiatives from the government in Goals 2000 and ESEA legislation, the National Science Foundation, and other agencies; and (3) that the window to address these issues will fast close as massive human and technology infrastructures are put in place without due regard for (e.g., National Center for Education and the Economy, 1990; Reich, 1992; Triangle Coalition for Science and Technology Education, 1989).

A Proposed Approach

The issues outlined above could become the incentives for coalitions and consortia to form regional initiatives The challenge is to think in terms larger than a school, district, or state, thereby sharing the cost of the human and technology infrastructure. Such an infrastructure is crucial to changing the opportunities to learn for millions of teachers, students, and administrators. Such an infrastructure also would give education the strength that it needs to maintain a place at the technology table on behalf of school children. Educators need to consider carefully the consequences of *not* having the political will to shape and manage technology opportunities as other organizations and groups are doing. Many key players are already organized in terms of regions that are fairly congruent. For example, there is considerable overlap in the Midwest among the following regionally-based institutions: Ameritech; Argonne National Laboratories; Central Education Network, a PBS affiliate; the Council of Great Lakes Governors; the Great Lakes Collaboration; Midwest Policy Institute; the technology network of the Committee on Institutional Cooperation (CIC) supported by the Big 10 and other universities; and NCREL. Forming interstate, regional and educational consortia would escalate many of those relationships significantly to create mutually beneficial enterprises.

In taking the technology challenge to a different level, old rules and relationships do not dominate; everyone is a learner, and a pioneer exploring new frontiers. For example, the cost of developing large repositories of digitized information resources is huge. Education, business, the military, and energy groups obviously can accomplish more on this task together than in isolation because they can work more economically and efficiently. If the appropriate players are at the table from the outset, school accessible information bases can be designed for multistate use, with each institution and agency contributing its particular core competencies for development.

The question has been asked, Why can't we just depend on the Internet? Unfortunately, the Internet does not yet have the capacity to deliver the full use of video and images effectively. Increasingly, these modalities will be the currency of information trading. Imaging is required to access much of the most interesting data from NASA and the U.S. Weather Service, museums, public libraries, and historical document collections—not to mention all of the fields that are essentially visual in nature, such as the medical sciences, advertising, and journalism. Nor can the Internet effectively deliver two-way interactive audio- and videoconferencing (other than desktop capabilities). Obviously, these technologies require powerful national and regional servers, ways for schools to share the costs of last-mile wiring for high speed telecommunications, and delivery systems for home communication with schools and other educational resources—all of which are very expensive.

A further problem is the interface between providers, the Internet, and schools. The providers provide content and some services such as curriculum development, ongoing professional development activities, and some technology training and support. The Internet is the vehicle which providers use to transmit all text-based and some image-based data and services. But many schools are really at a loss to use these data and services optimally. This is in part because they spend their energy in other directions, in part because they are not well-linked to the data and services, and in part because many, if not most, schools do not know how to use these data and services to restructure schools and schooling to promote engaged learning.

The point here is twofold. First, schools, not just teachers and administrators, need ongoing help in developing effective technology plans; in accessing the most recent research on learning; in restructuring their curricular frameworks schoolwide to focus on and integrate this wealth of free data and services; in funding strategies; and in coordinating school restructuring in school improvement plans. Second, the Internet and the emerging video and imaging technologies could be used to change the economic basis of schooling by changing how information and services are delivered to schools across the nation. That is, the content and services that are available through the Internet and other telecommunications—many of which are free or low cost—could ultimately replace most of the textbooks and other costly instructional materials, software, and programs that currently devour up most school budgets. If each school were to draw largely upon these free resources and services, schools could spend far more of their resources for additional staffing, local curriculum development, technology growth, development of technology staffing, ongoing local staff development, and school restructuring. Moreover, if schools all across the country were to do this, the economy of schooling would be radically altered.

How does all this relate to the question, Why can't we just use the Internet? The bottom line is that such massive and radical changes go well beyond the scope of the Internet or indeed any one agency. What is needed is a set of regionally-based agencies to coordinate the evolution/natural emergence of such trends—or to drive these trends as their primary agenda. Such agencies would have to be well-equipped, well-planned, and well-coordinated not just to deliver school restructuring services to schools to coordinate technology and learning but also to plan and monitor the massive economic changes such a redistribution could yield. Moreover, such agencies could have as part of their mission the need to address the many equity issues relating to technology and learning—especially providing help to poor rural and urban schools. Needless to say, there are in-depth policy issues inherent in such a bold initiative.

Scaling Up and Moving Out

What follows is an outline of some innovative regional agencies that could be critical to address issues of equity and economy. Specifically, we develop the idea of a regional information port, a regional school service cooperative, regional service universities, and educational enterprise communities that would form new kind of testbed, a testbed that focuses on region as the unit of change and deals with many of the political changes that are needed to support sustained change within a region.

Regional Info-Port. One strategy might be to create regional information distribution and coordination centers that would involve a diversity of players using the Internet and other free telecommunications. The Port would (1) transport low-cost or free resources for schools; (2) support school collaborations using video, audio, and text technologies, and focus on bringing the poorest schools in urban and rural contexts into collaborations; (3) link the schools to practicing scientists and community members across the globe—a task that will soon need much greater coordination than is now the case; (4) work with schools to develop technology plans, and work with higher education and other agencies to develop training and professional development programs for technology specialists and librarians; and (5) provide ongoing support for school restructuring to promote engaged learning—again especially for schools for the poor and minorities.

Each Port could be developed as an enterprise web (Reich, 1991). This would involve convening appropriate persons or agencies who are expert in all the areas necessary for successful adaptations and who would customize services for specific customers. Regional educational laboratories (RELs) could take the lead in convening the providers, the technology infrastructure agencies, and the schools. Each REL could convene the regional federal energy laboratory; representatives from museums, library systems, government agencies, universities, and other major providers; telecommunications providers; and various representatives of schools, intermediary units, and state education agencies.

Content providers might include libraries, museums, the U.S. Weather Service, oceanographic and anthropological researchers, disease control and other medical centers with public databases, and NASA. These content providers would be added to those directly servicing public education, such as the Department of Education, national R&D centers, technical assistance centers, RELs, universities, SEAs, and standard-setting agencies such as the National Board for Professional Teaching Standards and intermediary units agencies that are designed to support school and state education agency initiatives.

Regional Info-Ports would create a distributed technology infrastructure that could serve thousands of users simultaneously with quality resolution and access. The human infrastructure needed to develop this technology and to share in the costs could include a configuration of any of the following: computer companies, the Departments of Labor and Energy, telecommunication agencies, the power companies, local private sector groups, the military, technology support systems, and local civic organizations such as chambers of commerce and individual Rotary Clubs, in collaboration with the educational agencies described above.

Regional School Service Cooperative. In addition to an information port, there would be a need for service outreach—regional school service cooperatives. The goals of the service cooperative might include:

1. Helping **schools access and use the resources** available from the Internet and the Port in ways that both address national initiatives such as Goals 2000 and promote collaboration.

2. Promoting **equitable access** to and use of technology-enhanced learning opportunities for students, community members, and teachers.

3. Developing a new generation of **regionally based and supported learning communities** that define the learning place as wherever the learner can reach technologically: "virtual" and real learning places that would be open for use around the clock to serve various learning needs, and learning places in which the participants are both contributors and consumers of research, products, and services.

4. Developing **evaluation designs** for the use of technology and assistance in implementing those designs.

5. Studying and developing **new policies** to cover the new technology-supported learning contexts and situations, including policies and/or scenarios pertaining to the economics using Internet resources in place of or as a supplement to textbooks.

6. Providing **training and support services** to use technology and to develop plans to "grow" technology in schools so that teachers and students can use it as a tool to solve problems and address needs.

7. Working with schools to generate **learning experiences for professional development** including the development of roles such as digital librarian, project manager, computer specialist, and staff developer in an age of global technology.

The following are some of the human resource questions that will emerge and will need to be addressed by R&D: What are the qualities of successful technology specialists necessary to support school development in technology (a category not fundable in many schools)? How can they be trained so they can help schools make good decisions about learning, reform, and technology performance? Who should certify them, and who should train them? What is the role of a digital librarian? How will school-based projects be organized and indexed in libraries so that others in the school and learning community have friendly access to them. What are the standards of excellence in schooling for next generation professional staff, schools, and school systems? What are the characteristics of successful schools in a regionally based, global learning community?

To reach the cooperative's goals, it will be important to develop delivery systems that facilitate collaboration (problem solving, inquiry research, consulting, mentoring, technical assistance, and other services delivered electronically). But schools also will need to develop new learning outcomes and models that help transform rich, electronically accessed resources into usable and powerful formats for learning and teaching. Means will have to be found to organize and catalogue not only external resources and services, so that schools can use them better, but also resources, products, and services developed by schools. Indeed, clusters of schools might function as satellite enterprise webs, taking leadership in recruiting and mentoring novice schools. It also will be important to give participating schools latitude to reinvent schools using technology while still holding them accountable for standards of equity and excellence.

Regional Service Universities. A regional service university might be an actual physical entity set up by a consortia of universities in the region that had its own human, fiscal, and political infrastructure. Or such a university could be virtual in that it could be a set of courses operating as an "invisible college" without separate human, fiscal, and political infrastructures. The purpose of a regional service university it to provide services to schools and school networks subscribing to mutual programs and goals. Courses available from contributing members might emphasize using research and technology for systemic, long-term school restructuring. Distinctions among teacher educators and university students, school teachers, and students would become blurred as teacher educators provide services and co-development processes, while school teachers and administrators work as co-developers and contributors to the school development process. These regional universities might develop programs of study and certification for new roles for schools such as digital librarian and school technology specialist (Jones, 1994). At the moment, most colleges and universities offer certification for teachers, administrators, librarians (not trained in the new library technologies), and media specialists.

Educational Enterprise Communities. Increasingly, we are looking beyond individual schools to schools and communities as units of change. Several initiatives already exist as models. First, consider the city as the unit of change. The charter school movement, which concentrates on independently defined schools and school clusters, gives participants political permission within defined accountability structures to explore and develop new roles, rules, and relationships (NCREL Policy Brief, 1993). Municipalities as units of change—a concept developed in England by an Industrial Trust (see Abbott, 1988, 1990, in press)—also hold promise. Municipal efforts toward school and community learning can be seen in our country in programs such as Baltimore Reads, a public/private nonprofit initiated by the Mayor's office to engage institutions across the city in literacy so that schools, churches, business, libraries, and others would all be working to improve literacy skills.

Second, we also must look beyond cities and states to regions. The Learning Zone legislation being developed in our country seems particularly promising (Public Act 88-200, Illinois H.B. 2282). There is recent legislation, for example, from the Governor's Office in Illinois to grant 10 percent of the schools in Chicago many of the rights of Charter Schools. While Learning Zones are not quite as independent as Charter Schools, the involvement of 10 percent of the schools has the potential for a consortia that forms a networked system of education within the city. Such a zone could be strengthened dramatically through technology applications.

The Co-NECT Network is also a powerful prototype. As a national network, it already is exploring the uses of technology in ways suggested here. More specifically, the Co-NECT School Partnership is a coalition of American educators, corporations, and community leaders which began in the Commonwealth of Massachusetts, but has now expanded to other states. Led by Bolt, Beranek, and Newman, this Partnership won one of the New American Schools Development Corporation awards. It proposes a design that enables local communities to create their own break-the-mold schools in radically new arrangements and connections. Focused specifically on inner-city schools, the Partnership works with each community to develop a design that will work in any school using a concept driven by five components: (1) project-based curriculum founded on challenging, in-depth seminars; (2) performance-based assessment founded on a set of challenging standards; (3) school organization involving multi-age clusters that are self-managing; (4) a restructured school community, featuring self-managing clusters of students, teachers, administrators, and community members; and (5) a flexible and open computer-based communications network that supports the project-based curriculum and the restructured school community and links them to a rich array of local, national, and global resources (see Bolt, Beranek, & Newman, 1993).

Start-up funds and special status provided to small pilot groups of schools and local communities could permit them to explore the day-to-day realities and policy issues involved in constructing technology systems that serve effective learning. We envision Educational Enterprise Communities spreading out over a multistate area with schools and communities working together with teams to identify needs, design and create learning environments that address those needs, and develop policies through rapid prototyping. Technology itself, electronic connections, will encourage the enterprises to keep learning from each other.

Consider the opportunities that might result from a Regional Info-Port, Service Cooperatives, and Enterprise Zones linking various sectors of society and creating a regional community of learners:

- Schools, communities, and researchers working collaboratively to develop local and electronic communities together would restructure education, altering what is defined as education, what educational materials are, how they are delivered, where education is received, who uses educational resources, and what constitutes literacy, especially technological literacy.
- Publishers, researchers, universities, and others would deliver multimedia units of curriculum, instruction, and assessment directly to schools through Info-ports. Students and educators might take courses prepared or given live in other states, from other schools, or from the local district office. Teachers in different locations—for example, urban centers—could decide to collaborate to develop new curricula and opportunities to learn. The Algebra Project, for example, designed a transition curriculum for 6th, 7th, and 8th grades to bridge the conceptual gap many students experience between arithmetic and algebra, and to prepare students to enter college preparatory math in high school.

- Educators within a region could access regional banks with (1) multimedia prototypes for curriculum, instruction, and assessment units developed by standards boards, state education agencies, districts, regional laboratories, R&D centers, and universities; (2) curriculum frameworks, with shells and frames for local curriculum development, and an array of locally developed units of instruction contributed by experienced groups; (3) library materials on topics relevant to restructuring to promote learning; and (4) libraries of videos and CD ROMS with master teachers demonstrating particular instructional strategies.

- In schools with uplink capabilities for two-way video communication or with dishes able to receive programming, teachers could talk live to researchers and other teachers; watch a demonstration; present a demonstration for feedback; discuss diagnosing student problems; develop or co-develop integrated, multi-media materials with other teachers; exchange ideas on specific topics; develop video conferences; extend their own video libraries locally by downloading materials from the bank and by creating new videos of the best teachers locally; and participate in video clubs to discuss one another's work as professionals. Teachers also could develop demonstrations of their teaching for official critique and evaluation for professional certification.

- Participating schools might offer an array of services to community members from adult education courses to community outreach programs, renting out equipment and providing other school-generated services.

Info-ports, service cooperatives, and regional service universities are about restructuring access to quality information resources and collaboratively redefining education as a public institution. They are about stepping out of the roles, rules, and relationships that constrain, shifting the focus to community-building issues and rejecting the status quo in education. They are about finding common ground among diverse stakeholders, sharing human and other resources, unleashing energy to imagine and create, and about learning how to cooperate and build consensus to solve educational problems together. They are about building enterprise webs that serve to build new economic and political bases for education.

5. Next Steps for Research and Education

Need for a National Database

We believe there *is* a growing consensus about the good fit of the dimensions we and Means and her colleagues identified as sound systemic reform. At the same time, new technologies and studies of technology are emerging rapidly, constantly changing the outer limits of what is possible, what is now within reach. It is making less sense to rely on print medium to report these developments. Means, et al., do not cover many of the studies now available or emerging such as the Imaging Processing for Teachers project at the University of Arizona; CoVis at Northwestern University; NASA's newest Classroom of the Future; the network of schools supported by Goddard; the Co-NECT schools; many of the tools being developed at the federal energy laboratories, universities, museums, and libraries; and some of the newer software such as Mosaic developed by the University of Illinois-Champaign-Urbana, and Minuet developed by the University of Minnesota. What is needed is a national database and communication system that will provide both high-level, synthesized research in easy-to-read formats for policymakers at all levels, on one hand, and an in-depth database with rich details in various categories for researchers and educators, on the other.

Other questions and issues to include in a national database are: First, there is no common language to describe various ways "to grow" technology configurations in schools or districts. It would be helpful to apply Table 1 to specific learning and technology settings to get actual examples in each quadrant as well as to study how schools and districts move from one quadrant or paradigm to another. Second, many researchers who are developing technology programs have generated design features that should be examined systematically and comparatively. Third, analyzing the advantages and disadvantages of different implementation strategies could add a great deal to this literature. Schools and policymakers need such information to make decisions about implementing technology and learning goals.

If we had a national database, it would provide needed information, a common language, and a common location for the various pieces that support implementation. Policymakers, institutions of higher education, and educators alike would then have access to information that could answer such important questions as:

- How do successful schools "grow" technology expertise to address diverse technologies in the classroom as well as automated library systems?
- How do such schools expand the role of librarians and others in order to organize and disseminate the array of new curricular modules and information emerging from the schools' participation in various technology projects, including input from other libraries and museums?
- What kind of staff development principles and technologies are needed to support all of these evolving roles as well as the management of school operations, assessment, and finance?
- What architectures will best support learning, communication, and collaboration as well as provide equitable access to information for all students?
- What strategies do poor schools use to obtain funds for powerful technologies? Can there be a difference between the technologies of poor schools and more wealthy ones?
- What motivates people to persevere in establishing technology-enhanced schools? What methods effectively overcome barriers?

- What strategies have been successful in spreading an effective technology program from a few sites to many?

- What supports are required for successes in technology to be sustained, replicated, and combined with other technologies in order to become more powerful?

- How will the different video-based distance education technologies (such as broadcasts and cable) interface with the development of instructional programs available through the Internet? Will they be integrated? What new capabilities emerge with such an integration?

- Given how widespread VCRs and televisions are in schools and homes (Office of Technology Assistance, 1993), how can we stimulate or restructure the marketplace to provide incentives to develop more interactive television technologies to build on the existing video/television equipment in schools and homes?

- How can education benefit from the application of entertainment technologies such as Nintendo?

The focus on a national infrastructure should not suggest that we have all the needed research. Clearly, we are just at the beginning of a new era in learning and technology that is rapidly expanding and will be important to continue to study in the areas listed above, and others that will emerge.

Need for Tools

The framework developed in this paper provides a heuristic for technology learning evaluation. Ultimately, we will need tools to evaluate technology and learning that make it clear what a school's current realities are and compare this to its future vision. It must also be possible to compare one particular technology-enhanced program or curricula to another. Finally, it will be important to assist schools with inventories that help them identify preferable technology features and agencies that can support them. We have attempted to take a first step in this direction with the instruments in the Appendix.

Additionally, there is a need to document (a) what tools already exist for the various teaching and administrative functions such as curriculum development, management of records, and professional development; (b) what tools are available that help students access powerful databases, make decisions, solve problems, communicate, and (c) what tools are needed for these functions and for learning? These two agendas—the need for a national database on technology and engaged learning and the need for powerful tools for education and for those who support them—are vital to technology policy and to improving the use of technology in schools to promote engaged learning.

6. Recommendations for Policymakers and Educators

Implications of the Framework

As indicated above, some recommendations regarding technology policy for schools and other contexts emerge from Table 1 and considerations of regional infrastructures. This table would clearly *argue against strong support of a technology design that does not empower learning*, regardless of whether or not it is costly, and regardless of the dominant technology or medium. This does *not* mean abandoning technologies presently being used for low level learning goals, especially if they deliver instruction to those who would otherwise not have access to it, or provide access to information that would otherwise be unavailable. What is important, for example, in distance education and ILS, is adapting these technologies to support higher learning and educational reform goals so that students in remote and special locations can access programs that braid engaged learning with high performance technology. It is also very important to *support movement toward distributed networks as opposed to central source providers* to build communities of learners that include students and teachers as contributors.

This does not mean that all projects or services involving central source providers or software that is not networked should be abandoned. As noted above, there are some stellar projects, such as JASON, some of the NASA activities, *Ask the Scientist*, digital libraries, news and periodical services and others described above, that are essentially central source providers, but they provide a high quality product and service for schools that are highly motivating to teachers and students and promote engaged learning. The same is true for many tools that may or may not have open architecture and some of the high technology features, but which provide powerful opportunities for teachers to solve problems, develop curricula, and so on.

What is important in planning and in funding, regardless of the technology selected, is to connect technology to powerful learning paradigms. Such designs ideally allow students and teachers to (1) work on authentic, meaningful, and challenging problems; (2) interact with the data in user friendly ways that allow some student control of learning; (3) build knowledge together within a learning community that is broader than a few students or schools with similar characteristics and interests; and (4) interact with practicing professionals and community members.

Many schools can begin their involvement with technology-supported initiatives by investing in low-end technologies with high learning options. However, following Collins (1993), we strongly recommend that *schools become involved as soon as possible in pilots with some of the types of research-based providers* identified in this paper. It is important that these technology projects involve a significant group of teachers, and financial commitment as well; otherwise, it is not possible to experience what it means to use technology effectively for communication and for learning. Such projects should allow for experimentation with different models of instruction and different approaches to technology.

During this experimentation phase, schools can evaluate cost effectiveness in terms of the school's learning goals. If the school is not developing learning goals that link to Goals 2000, the technology learning paradigm in this paper may serve as a resource.

As the school's experience and expertise grow, it can progress to develop more powerful models of learning and reform using more complex technologies moving toward high-technology, high-learning options. *To move in this direction, schools must, from the outset, build the capacity to move as a school toward technologies that are more connected and powerful.* It is also important for schools that may be in the high-technology and low-learning arena to consider new options. They might move from closed-system ILS and distance education technologies that are providing direct instruction toward more interactive technologies, open architecture, connectivity to distributed resources, and more engaged learning paradigms for existing ILS and distance education technologies.

It is important to note that *investing in technologies without investing in ongoing professional development, training, and support services is counterproductive* and will ultimately be costly with limited payoff in learning. Successful technology programs with powerful impact are often supported by research-based agencies that focus on learning and collaboration. As business vendors seek to take on long-term roles, it will become important that they develop experience in research on learning and document evidence of student learning using their specific technologies and programs.

Summary

This paper begins by examining the new consensus in educational research. It discusses the consensus against traditional models of learning. Then, it examines the emerging consensus on learning and the emerging consensus on technology performance, discussing and defining a variety of indicators of each. These are highlighted within the text. Next, these indicators are related to learning and technology interactions and school-based policy through the use of various tables and frameworks. Local, state, and national policy issues crucial to engaged learning are highlighted next. From there, four changes in learning and educational reform are addressed. Problems that have arisen are mentioned and a proposed approach to solving these problems follows. The paper concludes by discussing possible next steps for research that allow the goals of engaged learning and high technology performance to be met.

The purpose of this paper is to describe effective technology use to support engaged learning. Toward that end, we conceptualize learning as a continuum from passive to engaged and technology as a continuum from low to high performance; that is, a continuum *from* low-performance technology that focuses on low-level objectives and interactions and uses a transmission model of learning *to* high performance technology that supports authentic tasks and powerful student roles such as explorer, cognitive apprentice, teacher, and producer. When we look at the intersection of these two continua, we can describe technologies and technology-enhanced programs in terms of the extent to which they support engaged learning, or learning by doing challenging, authentic tasks.

Overview of the Framework

Part 1 of the paper provides an analytic framework. We first defined technology effectiveness in terms of a successful interface between learning and technology. The intersection of the two continua displaying passive to engaged learning and low- to high-performance technology created a 2 x 2 matrix or fourfold table. The four patterns represented in the table are Engaged Learning/ High Technology (Category A), Engaged Learning/Low Technology (Category B), Passive Learning/Low Technology (Category C), and Passive Learning/Low Technology (Category D). (See Table 1, The Learning and Technology Interface, Appendix A.) The table demonstrates that technology is effective when its software design, hardware configuration, and operation is designed for engaged learning *and* when the technology maximizes access and use of interactive multimedia resources networked to a global learning community. In other words, engaged learning is only part of the picture; high-performance technologies have various capabilities that can redefine and extend the parameters of engaged learning.

Operationally, engaged learning with high technology would include technologies and programs such as:

- Networked projects with challenging tasks, access to the Internet, integrated multimedia capabilities including CD-ROM, two-way video conferencing, and access to professionals
- Distance education networked with computers, challenging tasks, links to work with practicing professionals
- Advanced, interactive multimedia tools and museum exhibits that promote thinking

In contrast, technologies and programs that include both high technologies, such as integrated learning systems, and traditional distance education programs are associated with passive learning because they (1) are used to transmit information from a central source for the student to "learn," (2) are focused on low-level objectives, and (3) do not link students to global resources. Similarly, computer-based instruction, video and audio used to transmit information (e.g., talking head), and computer literacy courses teaching programming skills as an end in itself are usually focused on low-level objectives and involve central source technologies.

This paper argues that a major goal of education should be to get as many schools as possible into Category A. Four different paths/trajectories allow us to reach this objective: Type I trajectory moves from Category D to B, Type II from B to A, Type III from C to A, and Type IV from D to A. This analytical framework can provide direction for policymakers wanting to use technology as a tool for classroom and school restructuring.

The New Consensus

When technology effectiveness is conceptualized as an intersection between learning and technology, it is possible to provide specific indicators of engaged learning and high-performance technologies that promote learning. Toward that end, Part 2 of this paper examines the research on learning and technology and finds increasing agreement. A striking feature of research is a strong reaction against traditional models of learning and technology and in favor of more engaged, authentic learning with collaboration. From this analysis, we developed 26 indicators of engaged learning and 25 indicators of high- performance technology.

Consensus Against Traditional Models and Definitions. There is a growing concern that traditional models of learning are not adequate to meet the needs of the 21st century and have thus become outmoded. It is clear that we need citizens who can think strategically to solve problems, learn in a constantly changing environment, build knowledge from a wide range of sources, understand systems in diverse contexts, and collaborate both locally and globally using technology. Such attributes contrast greatly with the low-level basic skills and content often being taught using the transfer/transmission model of instruction. Traditional approaches to measuring technology and cost effectiveness by comparing a technology-enhanced program to a traditional model of learning are inadequate. Technology effectiveness must be determined in relation to the extent to which it supports and extends engaged learning and collaboration. Cost effectiveness must be judged laterally, so to speak, in terms of comparing the cost of the various technologies and programs that are proposed to meet the learning goals. Once a technology plan has been established that has reasonable costs, relative to the goal, the cost effectiveness must be judged in terms of getting the best purchase for equipment, software, training, and services.

Emerging Consensus on Learning. Across various strands of research, there is increasing consensus on what constitutes the key variables of learning and instruction and on what defines engaged learning in the classroom and school. Jones (1992) has synthesized the research and identified eight variables of instruction, which were updated for the purposes of this paper: (1) the vision of learning, (2) the tasks that define the nature and level of achievement, (3) the assessment principles and practice, (4) the instructional model, (5) the characteristics of the learning context, (6) building classroom organization, (7) the learner roles, and (8) the teacher roles.

To develop specific indicators within each of these categories of learning and instruction, we looked at basic research and theory as well as syntheses of that research base and find many commonalities; e.g., the American Psychological Association (1993), Brooks and Brooks (1993), and Means, et al. (1993). From this rich set of resources, we selected the indicators developed by Means and her colleagues as a guide to develop specific indicators of engaged learning within each of the eight categories in the analytic framework. Specifically, Means and her colleagues identified seven indicators to measure what they called effective learning and reform instruction: authentic and multidisciplinary tasks, performance-based assessment, interactive modes of instruction, heterogeneous groupings, collaborative work, student exploration, and teacher as facilitator. The descriptions of the indicators for each of the eight variables in our framework follow. (See also Table 2: Engaged Learning and Reform Instruction, Appendix A.)

1. Indicators: Vision of Engaged Learning. What does engaged learning look like in students? Successful, engaged learners are *responsible for their own learning*. These students are self-regulated and able to define their own learning goals and evaluate their own achievement. They are also *energized by their learning*; their joy of learning leads to a lifelong passion for solving problems, understanding, and taking the next step in their thinking. These learners are *strategic* in that they know how to learn and are able to transfer knowledge to solve problems creatively. Engaged learning also involves being *collaborative*, that is, valuing and having the skills to work with others.

2. Indicators: Tasks for Engaged Learning. In order to have engaged learning, tasks need to be *challenging*, *authentic*, and *multidisciplinary*. Such tasks are typically complex and involve sustained amounts of time. They are authentic in that they correspond to the tasks in the home and workplaces of today and tomorrow. These tasks often require integrated instruction that incorporates problem-based learning and curriculum by project.

3. Indicators: Assessment of Engaged Learning. These assessments involve presenting students with an authentic task, project, or investigation, and then observing, interviewing, and/or examining their artifacts and presentations to assess what they actually know and can do. This is called *performance-based* assessment. This assessment is *generative* in that it involves students in generating their own performance criteria and playing a key role in the overall design, evaluation, and reporting of their assessment. The best performance-based assessment has a *seamless* connection to curriculum and instruction so that it is *ongoing*. Assessment should represent all meaningful aspects of performance and should have *equitable* standards that apply to all students.

4. Indicators: Instructional Models and Strategies for Engaged Learning. The most powerful models of instruction are interactive—instruction actively engages the learner—and generative—instruction encourages the learner to construct and produce knowledge in meaningful ways. Students teach others interactively and interact generatively with their teacher and peers. This allows for co-construction of knowledge, which promotes engaged learning that is problem-, project-, and goal-based. Some common strategies included in engaged learning models of instruction are individual and group summarizing, means of exploring multiple perspectives, techniques for building upon prior knowledge, brainstorming, Socratic dialogue, problem-solving process, and team teaching.

5. Indicators: Learning Context of Engaged Learning. For engaged learning to happen, the classroom must be conceived of as a *knowledge-building* learning community. Such communities not only develop shared understandings collaboratively, but also create *empathetic* learning environments that value diversity and multiple perspectives. These communities search for strategies to build on the strengths of all of its members. Truly *collaborative* classrooms, schools, and communities encourage students to ask hard questions, define problems, lead conversations, set goals, have work-related conversations with adults in and out of school, and engage in entrepreneurial activities.

6. Indicators: Grouping for Engaged Learning. Collaborative work that is learning-centered often involves small groups or teams of two or more students within a classroom or across classroom boundaries. *Heterogeneous* groups (including different sexes, cultures, abilities, ages, and socioeconomic backgrounds) offer a wealth of background knowledge and perspectives to different tasks. *Flexible* grouping, which allows teachers to reconfigure small groups according to the purposes of instruction and incorporates frequent heterogeneous groups, is one of the most *equitable* means of grouping and ensuring increased learning opportunities.

7. Indicators: Teacher Roles for Engaged Learning. The role of the teacher in the classroom has shifted from the primary role of information giver to that of facilitator, guide, and learner. As a *facilitator*, the teacher provides the rich environments and learning experiences needed for collaborative study. The teacher is also required to act as a *guide*, a role that incorporates mediation, modeling, and coaching. Often the teacher also is a *co-learner* and/or *co-investigator* with the students.

8. Indicators: Student Roles for Engaged Learning. One important student role is that of *explorer*. Interaction with the physical world and with other people allows students to discover concepts and apply skills. Students are then encouraged to reflect upon their discoveries, which is essential for the student as a *cognitive apprentice*. Apprenticeship takes place when students observe and apply the thinking processes used by practitioners. Students also become teachers themselves by integrating what they've learned. Hence, they become *producers* of knowledge, capable of making significant contributions to the world's knowledge.

Emerging Consensus on Technology Performance. Upon looking at technology through the lens of learning, six analytic categories were developed to examine technology performance: (1) school access to diverse technologies and resources both beyond the school and within a given classroom, (2) operability, (3) location and direction of resources, (4) capacity to engage students in challenging learning, (5) ease of use, and (6) functionality. There is, again, a strong consensus among researchers that technology artifacts can be designed to promote engaged learning. There are indicators within each of the six technology performances that would yield high performance and would promote engaged learning and reform instruction. (See also Table 3: High Performance Technology and Engaged Learning, Appendix A.)

1. Indicators: Access. A vital indicator of high-performance technology is its access. A technology has high-performance in terms of access when it has connectivity, ubiquity, and interconnectivity. *Connectivity* refers to the capability of technology to access rich resources within and beyond the school because it is connected to those resources. *Ubiquity* means that technology equipment must be everywhere within the district so that all teachers and students can access and use it as a learning tool. Interactivity refers to the interaction that occurs when students and teachers actually communicate and collaborate in diverse ways. Additionally, it is imperative that there is a powerful *design for equitable use* of technology so that *all* students have access to the learning tools that provide high-quality, challenging opportunities to learn.

2. Indicators: Operability. Once there is proper access, **operability** must be considered. A technology has maximal performance in terms of operability when it has *interoperability*, "the capacity to easily exchange data with and connect to other hardware and software to provide the greatest access to all students." To achieve this, it is necessary to have *open architecture*, which allows users to access data using different hardware and software, and sometimes lets them modify the system. Interoperability also requires *transparency*, or the ability to move easily from one format or program to another. This feature promotes engaged learning by allowing users to spend maximal time using the resources for multiple tasks rather than engaging in complex procedures for moving among formats/programs.

3. Indicators: Organization of resources. These indicators refer to where information/data is stored, how resources are connected, how new resources get into the system, and who is in charge. In order to attain both high performance and engaged learning, resource systems should be *distributed* rather than centralized. Distributed resources are socially constructed through collaborative efforts. They are designed for *user contributions*. That is, information can be contributed to the system from multiple sources so that many users can share the data. Moreover, such systems typically involve tools that are designed for *collaborative projects*, such as on-line conferences, bulletin boards, and access to remote files. These capabilities help in creating a knowledge-based community.

4. Indicators: Design Features for Engaged Learning. Technology should include design features that promote engaged learning. One such feature is for the software itself to *provide challenging learning tasks, opportunities, and experiences*. This includes links to museums and libraries, access to expert and community members, use of rich media such as 3-D and virtual reality, and tools for interactive browsing. Another feature is software that allows students to *learn by doing*, using goal-based scenarios, problem-based learning, and simulations. Such tools allow the user to plan, reflect, make decisions, experience the consequences of actions, change directions, and examine alternative solutions and assumptions. In addition, the system should provide *guided participation*; for example, the capacity to customize the content or to allow students to share their files with their peers. A final indicator is the capacity of the system to provide information that is *just in time and just enough*.

5. Indicators: Ease of Use. It is essential that the programs be *user-friendly* and that they include *effective help* opportunities. It is also necessary that the system be *speedy* and provide feedback. Along these lines, *user control* of the system is important to access tools and use them however needed. *Training and support* to use the technology is vital and should be available from both local and remote locations. These ease-of-use features help the learner access the resources and the learning experiences offered by the system.

6. Indicators: Functionality. Technology should be able to prepare learners for the diversity of technology functions that are basic to learning in the 21st century. Students should make frequent use of *multimedia technologies* and *generic tools* and have opportunities to use *work-specific technologies*. Technology should also prepare students to *use tools that create tools*, as well as provide opportunities to learn *programming and authoring* skills to create new programs and tools for others to use. Software should likewise allow students to develop skills related to *project design and implementation* such as setting goals, developing budgets, preparing analyses, and so forth.

Learning and Technology Interactions and School-Based Policy. Technologies and technology-enhanced programs need to be measured by the extent to which they support engaged learning and educational reform. To this end, we have identified two ways of analyzing the intersection of learning and technology: develop tools to score the indicators and apply the concepts of engaged learning and high-performance technologies to examine the intersection in broad terms. To accomplish the first approach, we have developed a series of empowering tools—which are included in the body of the paper and in the Appendix—that schools can use for a variety of purposes: to define their current realities and then use this assessment to help evaluate and design future goals of where they want to go from there; and to compare one program to another. In broader terms, technologies such as e-mail, computer-aided instruction, integrated learning systems, and distance learning can be examined from the perspective of engaged learning and high performance technology to evaluate their capacities, designs, and uses in school. These examinations of technology reiterate the point that technology effectiveness should be defined in terms of how well it supports engaged learning and instructional reform.

Local, State, and National Policy Issues. In order for schools to use technology to promote engaged learning, certain elements inside and outside of the classroom must be in place. Five important policy issues have been identified that greatly affect a school's ability to employ technology in classrooms to promote engaged learning experiences. These include universal participation, high-quality technology access for all students, student familiarity with workplace technologies, commitment to ongoing professional development, and the role of the parents.

The first policy issue concerns equity or universal participation: every student in every school must have access to and active involvement in the emerging information highway that will connect them with the world. It is crucial that this connection be implemented at a local level under the guidance of local policymakers. There are, however, notable barriers that prevent school participation, such as a lack of (1) focus and time for quality technology training, (2) models of instruction that promote engaged learning and effective use of technology, and (3) school architecture that supports a community of learners. It is important for policymakers to consider these barriers as they develop legislation.

A second policy issue lies in providing high quality technology access for all students to achieve high standards of academic excellence. Student use of quality resources will not happen without an ongoing commitment to developing high standards for technology access and use through specific policies and financing strategies. Major barriers to implementing these policies at the local level are (1) local assessments that focus on low level and conventional objectives, (2) fragmented technology initiatives, and (3) tracking systems that separate students and technology into low- and high-level applications.

The third set of policy issues focuses on the coordination of technology choices with uses in the workplace. The transition from school to work can be greatly strengthened by allowing students to become familiar with workplace technologies. Experience using technology with high transfer to the community and workplace is important.

The fourth policy issue surrounds commitment to ongoing professional development that prepares educators to implement the proposed instructional strategies. This has important implications for building planning and classroom management as well as seamless curriculum, instruction, and assessment.

One final important issue is the role of technology for parents. Historically, groups of parents across the nation have not supported initiatives focused on teaching thinking. When this fear is coupled with technology, parents could feel very threatened if they are not brought into the partnerships.

Learning, Educational Reform, and Technology

Part 3 of the paper examines four changes that are defining educational reform. First, the strong movement to create a National Information Infrastructure and open up the Internet to schools has created significant resources for curriculum, instruction, and assessment models for schools and for professional development. Second, inherent in the growth of the Internet is the emergence of new content and service providers (such as government departments, public and private agencies, universities, and broadcasters). Through these providers, networked schools can receive up-to-the-minute data from around the globe and ongoing professional development support, as well as import curriculum frameworks and materials to construct their own projects and curricula.

Third, the growing skepticism about the use of standardized tests has led to a growing focus on student performance on authentic tasks and projects in the context of real audiences. One important new concept for technology and program evaluation is the notion of national testbeds, where teachers, students, scientists, educational researchers, and administrators work together to develop expertise and to evaluate the costs and benefits of a given technology or program. There is increasing evidence that technologies and technology programs that promotes engaged learning make a significant difference on curriculum, student achievement, professional development, and restructuring. Indeed, good, research-based technology programs seem to accelerate both classroom and school restructuring.

Fourth, renewed interest and funding in school-to-work transition is linking workplace technologies with secondary and postsecondary educational experiences. Also, it is vital to redefine technology literacy in terms of preparation of students for the technology functions such as databases and spreadsheets needed in the workplace, community, and home.

Regionality as a Unit for Learning/Technology Paradigms

Part 4 of the paper examines the role of these changes in technology for education as a public institution. In particular, we examine the problems that technology creates and propose some solutions using the concept of regionality as the unit for change.

Universal Access and Technology Growth as Problems for Education. There is no question that with the changes redefining educational reform, there is a need to develop an effective human and technology infrastructure that focuses on engaged learning. Education needs to be at the table with business, the telecommunications industry, the power companies, and others when vital issues of access to information are decided. Questions need to focus on how to configure technology to support engaged learning and collaboration for all students—the equity issues; how all schools can have economical, two-way access to important public databases and resources; how can school regulations be changed to provide training and ongoing professional development, not just for teachers and administrators but also for librarians and technology specialists; and how can institutions that relate to schools change to provide better support so that schools use the available resources and participate as co-investigators and producers of knowledge and technology.

Technologies are expected to reduce inequities in learning because in theory they can provide universal access to information. However, problems can arise in many poor schools, which do not have the funds, curricula, and/or faculty to participate in technological advancement. These schools are often hindered by their own bureaucracies that keep communication and development from moving beyond the walls of the schools into business and community sectors. It is possible, therefore, that richer schools that can access information and resources will become "information richer" while the poorer schools, in effect, become "information poorer."

Four related problems also exist. First, there are limitations to the factory model of schooling in curriculum, instruction, and assessment. Top-down management and high volume have served as the economy of public education as an institution. Second, systematic reform in the cities has long been challenged by school funding formulae that depend on residential property taxes. If education is to change, the tax and funding structures of schooling must be a part of that change. Third, the scale up challenge will probably require the formation of new organizations and consortia. It seems unlikely that any one institution or agency will be able to provide very large-scale technology services to school and still maintain quality services. Fourth, there are broader economic reasons to think about strategies that go beyond a given city or state. The purchasing power of a multistate agency is far greater than that of a single state.

A Proposed Approach for Scaling Up and Moving Out. With these problems in mind, a proposed solution is to form regional initiatives, which go beyond the school, district, or state level. Such infrastructures could facilitate opportunities for shared costs, broader learning opportunities, more equitable distribution of resources, and the strength that education needs to become a major player in today's growing technological society. These capabilities are beyond the scope of the Internet. What is needed is a set of regionally-based agencies to coordinate the evolution of technological trends. Such agencies would not only help restructure schools to coordinate technology and learning, but they would also plan and monitor the massive economic changes such a redistribution of services could yield. There are several possible strategies for developing innovative regional agencies:

Regional Info-Port. One strategy is to create regional information distribution and coordination centers that would involve a diversity of players using the Internet and other free telecommunications. Such a port would then transport low-cost and/or free resources to schools, support school collaborations, link schools to scientists and community members around the world, work with schools to develop technology plans and higher education to develop training and professional development programs, and provide ongoing support for school restructuring to promote engaged learning.

Regional School Service Cooperative. In addition to an information port, there would be a need for service outreach—regional school service cooperatives. These would help schools access and use their resources, promote equitable access to technology-enhanced learning opportunities, develop regionally based and supported learning communities, develop technology evaluation designs, develop new policies, provide training and support services, and generate learning experiences for professional development.

Regional Service Universities. A third possibility is a regional service university, which would provide services to schools and school networks subscribing to mutual programs and goals. Courses available from contributing members might emphasize using research and technology for systemic, long-term school restructuring.

Educational Enterprise Communities. Increasingly, we are looking beyond individual schools to schools and communities as units of change. Several initiatives already exist as models such as the charter school movement and municipal efforts such as Baltimore Reads. Then, we must also look beyond cities and states to regions. The Learning Zone legislation being developed seems promising.

Info-ports, service cooperatives, and regional universities are about restructuring access to quality information resources and collaboratively redefining education as a public institution. They are about building enterprise webs that serve to build new economic and political bases for education.

Next Steps for Research and Education

The next step for research and education will focus on some basic needs. There is a need for development of rich databases that describe successful technologies and programs as well as a communication system that will provide high-level research information for policymakers and a detailed database for researchers and educators. A second need relates to training and professional development. Right now schools are heavily dependent on commercial vendors for advise on what technologies to purchase and how to configure them as well as for training. There are few places they can access for research-based information about technology and engaged learning, the power and resources of the Internet, and useful advise about building architecture and requirements to support 21st century technology. Thus, there is a great need to disseminate information about these databases and tools that help schools address these issues and to evaluate technology and learning.

Recommendations for Policymakers and Educators

Some recommendations regarding technology policy for schools and other contexts emerge from this paper. First, strong support should be given to technology designs that empower learning. It is also important to support movement toward distributed networks as opposed to central source providers. In terms of planning and funding, it is important, regardless of the technology selected, to connect technology to powerful learning paradigms that allow students and teachers to work on authentic and challenging problems, interact with the data in ways that allow student control, build knowledge within a learning community, and interact with practicing professionals and community members.

It is recommended that schools become involved as soon as possible in pilot programs with research-based providers. Also, in order to move toward high-technology, high-learning options, schools must build the capacity to move toward technologies that are more connected and powerful. Finally, it is important to note that investing in technologies without investing in ongoing professional development, training, and support services is counterproductive and will ultimately be costly, with limited payoff in learning. These recommendations will allow our schools to use technology to its fullest potential and, hence, move toward a more successful learning endeavor.

APPENDIX A

TABLES DEFINING THE INTERSECTION OF LEARNING AND TECHNOLOGY

For the convenience of the reader, Tables 1-3 have been reprinted here with glossaries. All three tables related to the interaction of learning, defined as a continuum from passive to engaged. and technology defined as a continuum from high performance technology that promotes engaged learning to low performance technologies that do not. Table 1 shows the four categories that emerge when these two variables intersect. Table 2 provides indicators for eight categories of engaged learning with a Glossary defining the 26 indicators. Table 3 provides indicators for high performance technologies that promote learning with a Glossary defining the 25 indicators.

The form below is designed to assist the user to focus on the appropriate unit of analysis:

Name of User:______________________________

Unit of Analysis: (check one)

TABLE 1

THE LEARNING AND TECHNOLOGY INTERFACE

High

TECHNOLOGY PERFORMANCE

Low

(C) **Examples** -Closed integrated learning systems focusing on low level objectives and standardized, objective assessments -Traditional distance education used to transmit information from a central source and focused on low level objectives and assessments (talking head) -Connections to homes that are linked only to closed networks for the school and vendor and perhaps to other schools using the same vendor	(A) **Examples** -Networked projects with: challenging tasks, access to Internet, integrated multimedia capabilities including CD-ROM, two-way video conferencing, access to professionals - Distance education networked with computers; challenging tasks; linked to work with real-world professionals and data; two-way video -Advanced tools and high-technology museum exhibits that are interactive and support high-level thinking
(D) **Examples** -Computer-based instruction/drill and practice focusing on low level objectives -Instructional television focused on low level objectives -Video and audio used to transmit information as a lecture or talking head -Teaching a computer language or word processing as an end in itself as technology literacy	(B) **Examples** -Projects using multimedia experiences and data provided by CD-ROM for authentic and challenging learning -Local file sharing allowing students access to all files for communal editing and development -E-mail for inquiry collaborations -State network support for schools using the Internet for projects

Passive Learning ==================== **Engaged Learning**

LEARNING

TABLE 2

ENGAGED LEARNING AND REFORM INSTRUCTION

Variables of Learning and Instruction	**Indicators for Engaged Learning and Reform Instruction**
Vision of Learning	Responsible for learning Strategic Energized by learning Collaborative
Tasks	Authentic* Challenging* Integrative/Interdisciplinary*
Assessment	Performance-based* Generative Seamless and ongoing Equitable
Instructional Modes	Interactive* Generative
Learning Context	Collaborative* Knowledge building Empathetic
Grouping	Heterogeneous* Equitable Flexible
Teacher Roles	Facilitator* Guide Co-Learner/Co-Investigator
Student Roles	Explorer* Cognitive apprentice Teacher Producer

* Shows indicators provided by Means and her colleagues (1993).

GLOSSARY FOR TABLE 2

VISION OF LEARNING

Responsible for Learning - learner involved in setting goals, choosing tasks, developing assessments and standards for the tasks; has big picture of learning in mind

Strategic - learner actively develops repertoire of thinking/learning strategies

Energized by learning - learner is not dependent on rewards from others; has a passion for learning

Collaborative - learner develops new ideas and understanding in conversations and work with others

TASKS

Authentic - pertains to real world, may be addressed to personal interest

Challenging - difficult enough to be interesting but not totally frustrating, usually sustained; requires creative and or critical thinking

Integrative/Interdisciplinary - involves integrating disciplines to solve problems; address issues

ASSESSMENT

Performance-based - involving a performance or demonstration, usually for a real audience and useful purpose

Generative - learner constructs the knowledge and artifacts assessed, ideally learner generates performance criteria and contributes to overall assessment plan

Seamless and ongoing - assessment is part of instruction and vice versa; students learn during assessment

Equitable standards - assessment is culture fair and standards apply to all

INSTRUCTION/MODEL

Interactive - teacher and students actively engaged in learning with each other and with instructional resources

Generative - instruction oriented to constructing meaning; providing meaningful activities/experiences

LEARNING CONTEXT

Collaborative - instruction conceptualizes students as part of learning community; activities are collaborative within and across classroom boundaries

Knowledge building - learning experiences set up to bring multiple perspectives to solve problems such that each perspective contributes to shared understanding for all; goes beyond brainstorming to construct meaning

Empathetic - learning environment and experiences set up valuing diversity, multiple perspectives, strengths

GROUPING

Heterogeneous - small groups involve persons from different ethnic cultures and backgrounds, genders, and abilities

Equitable - small groups organized so that over time all students have challenging learning tasks/experiences

Flexible - different groups organized for different instructional purposes so each person is member of different groups based on need and/or interests

TEACHER ROLES

Facilitator - stimulates and monitors discussion and project work but does not control; negotiates with students and others

Guide - helps students to construct their own meaning by modelling, mediating, explaining when needed, redirecting focus, providing options

Co-Learner/Co-Investigator - teacher considers self as learner; willing to take risks to explore areas outside his or her expertise; collaborates with other teachers, students, and practicing professionals

STUDENT ROLES

Explorer* - students have opportunities to explore new ideas, new tools; push the envelope in ideas and research; engages in frequent discovery-oriented, open-minded activities

Cognitive Apprentice - learning is usually situated in relationship with mentor who coaches students to develop ideas and skills that simulate the role of practicing professionals (e.g., engage in real research); student observes, applies, and refines through practicing the thinking processes of the practitioner

Teacher - students encouraged to teach others in formal and informal contexts

Producer - students develop products of real use to themselves or others

TABLE 3

HIGH PERFORMANCE TECHNOLOGY AND ENGAGED LEARNING

Variables of Technology Performance	**Indicators for High Technology Performance -> Engaged Learning**
Access	Connectivity Ubiquity Interactivity Design for equitable use
Operability	Interoperability Open architecture Transparency
Resource Organization	Distributed resources and logic/intelligence User contributions Design for collaborative projects
Engagement	Opportunities for challenging tasks and experiences Opportunities to learn by doing Guided participation and intelligent tutoring Information just in time and just enough
Ease of Use	Effective helps User friendly User control Training and support Speed
Functionality	Use of multimedia technologies Use of generic tools Use of context-specific (work-specific) tools Programming/authoring skills Design and project implementation skills Use of tools that are used to make tools/programs

GLOSSARY FOR TABLE 3

ACCESS

Connectivity -- schools connected to Internet and other resources

Ubiquity -- diverse technologies (computers, printers, facsimiles, video) near where students and teachers need them; available to critical mass per classroom

Interactivity -- refers to active use of technology

Design for equitable use -- planning for all students to access and use technology and programs that are high quality and challenging

OPERABILITY

Interoperability -- capability to exchange data among diverse technologies easily

Open architecture -- allows users to access "third party" software; contrasts with closed systems

Transparency -- users not aware of procedures to change programs and data

RESOURCE ORGANIZATION

Distributed resources -- assumes that intelligence and resources reside in diverse locations; contrasts with centralized system that controls all resources

User contributions -- users can provide input/resources to the system on demand

Design for collaborative projects -- designed to facilitate communication among users with diverse technologies; not communication with central source

ENGAGEMENT

Opportunities for challenging tasks and experiences -- software provides tasks/data and learning opportunities that stimulate thought and inquiry

Opportunities to learn by doing -- software provides simulations, goals based learning, real-world problems

Guided participation and intelligent tutoring -- system responds to student use intelligently; is able to diagnose and prescribe new learning

Information just in time and just enough -- random access; multiple points of entry; different levels and types of information

EASE OF USE

Effective helps -- system provides help indices that are more than glossaries; may provide procedures for tasks and routines

User friendly -- user enjoys use; is not burdened by long delays and overly complex procedures

Training and support-- system provides both technology training and training in applications and ongoing support

Speed -- system not down for long delays

FUNCTIONALITY

Use of multimedia technologies -- e.g., color printers, integrated media driven by computer, video, audio, fax

Use of generic tools -- e.g., spreadsheets, databases, word processing

Use of context specific tools -- work specific technologies; e.g., computer-assisted drawing

Programming and authoring skills -- teaches students how to create their own tools and programs

Technology-related design and project implementation skills -- software that helps users comprehend and use skills for designing and implementing different kinds of projects (e.g., project scheduling and budgeting)

Use of tools that are used to make tools/programs -- system provides wizards and other tools that are used to make tools

APPENDIX B: COMPARING CURRENT REALITIES AND FUTURE GOALS

Appendix B is a series of three tables to use in various contexts to plot current realities and future goals with regard to **actual practice** (what is in place in the classroom and school with regard to technology use) and with regard to **policy** (what is in place in plans, mission statements, curricula frameworks, assessment programs, and the like that determine school and/or district policy). The scoring system we have developed allows users to indicate the level of involvement or development with regard to that indicator at the practice level and at the policy level. To elaborate what is meant by practice and policy, consider the following example comparing two hypothetical schools in terms of authentic tasks.

> Example: School A has only just begun developing such tasks through a very powerful technology program they are piloting (learning practice). They have implemented the program as part of their new mission to become aligned with the learning and technology needs of the 21st century (learning and technology policy). In contrast, many teachers at school B have been developing authentic tasks through the school's assessment program (learning policy), and this development is a major strength. School B has almost no technology in place (technology practice), but it has become a major agenda in their school improvement plan (technology policy).

Each table is shown twice: (1) a completed version using data from a hypothetical school and (2) a blank version so that users can have it for local applications. Tables 4, 5, and 6 have been completed using hypothetical data; Tables 4a, 5a, and 6a are blank. Each table is followed by a legend that tells users how to fill it in. **It is very important to understand that Tables 4, 5, and 6 represent indicators only for Category A on Table 1: engaged learning that is braided with high performance technology.** There is a point of view presented in this paper that says that every school or user should be working toward the ideal of very engaged learning that is supported and extended by high performance technology.

It should be noted that these are tools for <u>every school</u> and <u>every program</u>, regardless of current status of that school or program with regard to learning and technology. Every school or program will have a mixed profile—some scores that indicate the presence of engaged learning and/or high performance technology practice and policies; and some scores that reflect lack of development. Moreover, we believe that most schools are in the midst of changing.

Table 4 on the next page allows users to score where they are <u>now</u> in terms of what indicators would describe their current realities for learning and for technology. The data is hypothetical but reflects characteristics of schools as they exist today. The Legend for Table 4 shows the values for Practice and Policy Scores. Following that is an abbreviated scenario of how a hypothetical school would score itself on engaged learning and high performance technology.

TABLE 4: CURRENT REALITIES FOR SCHOOLS

ENGAGED LEARNING AND HIGH PERFORMANCE TECHNOLOGY

Engaged Learning Indicators	**Practice Scores**	**Policy Scores**
Vision of Learning		
Responsible for learning	0**	2
Strategic	3	3
Energized by learning	2	1
Collaborative	1	1
Tasks		
Authentic*	1	3
Challenging*	1	1
Integrative/Interdisciplinary*	3	3
Assessment		
Performance-based*	2	3
Generative	2	1
Seamless and ongoing	1	1
Equitable standards	2	3
Instruction/Model		
Interactive*	3	3
Generative	2	2
Learning Context		
Collaborative*	2	3
Knowledge building	0	2
Empathetic	2	3
Grouping		
Heterogeneous*	3	3
Equitable	1	3
Flexible	2	1
Teacher Roles		
Facilitator*	2	3
Guide	1	2
Co-Learner/Co-investigator	1	1
Student Roles		
Explorer*	1	3
Cognitive apprentice	3	3
Teacher	0	1
Producer	1	0
Total Scores	42	55

High Performance Technology Indicators	**Practice Scores**	**Policy Scores**
Access		
Connectivity	3	2
Ubiquity	3	2
Interactivity	3	2
Design for equitable use	1	2
Operability		
Interoperability	3	3
Open architecture	3	3
Transparency	3	3
Resource Organization		
Distributed resources	3	3
User contributions	3	3
Collab. Projects/Design	3	3
Engagement		
Opportunities for challenging	3	3
tasks and experiences	-	-
Opportunities to learn by doing	2	3
Guided participation and	2	1
intelligent tutoring	-	-
Info. just in time and just enough	1	0
Ease of Use		
Effective helps	3	3
User friendliness	3	3
User control	3	3
Training and support	1	3
Speed	3	3
Functionality		
Use of multimedia technologies	3	3
Use of generic tools	2	1
Use of context-specific tools	0	0
Programming and authoring skills	1	2
Design and project skills	2	3
Use of tools to make tools	0	0
	57	57

*Indicators provided by Means, et al., 1993

**All numbers represent hypothetical scores.

Legend for Table 4: Current Realities

Scores for Learning Practice are marked on a scale from 0-3

0 = Not in place at this time.
1 = Some users/teachers exploring/piloting/developing.
2 = Many users/teachers have good skills in these areas; practice is effective.
3 = Most users/teachers have mastery, and practice is very widespread; it is a major strength for the school.

Scores for Technology Practice are marked on a scale from 0-3

0 = Not in place at this time.
1 = Some users/teachers have equipment and are exploring/piloting/developing.
2 = Many users/teachers have good computer and technology skills and are actively engaged with the technology.
3 = Most users/teachers have mastered complex technologies (hardware and software) and effective use of technology to promote engaged learning and instruction is a major strength in the school or district.

Scores for Policy are marked on a scale from 0-3.
Policy Scores refer to what the school/community values for a given indicator. This value must be shown in some kind of policy such as a mission statement, a curriculum framework, an assessment system, building organization policy, or a design or plan that has been accepted.

0 = not in place
1 = not so important
2 = somewhat important
3 = very important

Rationale for Some Sample Practice and Policy Scores. This hypothetical school has a lot of thinking skills programs that are quite motivating, so they think they have some important things in place with regard to their Vision of **Learning**; that is, thinking of learners as Strategic and Energized by learning. Accordingly, the staff gives Practice Scores of 3 and 2, respectively, to those Learning Indicators, and 3 and 1 for the Policy Scores. However, they noted in doing this self-assessment that they really did not have anything in place that specifically addressed student Responsibility for learning in the ways defined here, even though student responsibility for learning is stated in two of the curriculum frameworks. So they gave a Practice score of 0 and a Policy Score of 2. Regarding Collaborative, there is much staff enthusiasm for what we at the school call "cooperative learning," which is highly structured, not the characteristics of collaborative learning given in the text of this paper. So staff gave themselves a Practice Score of 1 on this Learning Indicator because some teachers were experimenting with less structured cooperative learning paradigms. They gave themselves a 1 for the Policy Score because the Beliefs Statement the school developed last year referred to the need for "learning in group contexts."

Moving to the next category, many of the staff would have liked to give themselves a 3 for all three Indicators of engaged learning for the **Tasks** variable. But the current reality is that while the staff talked about the need for tasks that were Authentic and Challenging, in fact only a few of the staff were developing such tasks, and they were not tasks that were as "rich" as those we described, so they decided that they should rate themselves Practice Scores of 1 for both indicators. The Integrative/Interdisciplinary was easy. They have had such projects for years so they gave themselves a Practice Score of 3. However, when it came to the Policy Scores, their curriculum frameworks talk a lot about Authentic tasks, so they gave themselves a 3, as was the case for Integrative/Interdisciplinary. But they really had no shared language for Challenging, so they gave themselves a Policy Score of 1.

The paragraphs above should give the user a sense of how this table should be used—reflectively by a group of persons, thinking about what is in place and what is valued in the shared artifacts of the school and comparing the definitions in the text here with policies and actual practice at the school.

TABLE 4a: CURRENT REALITIES

FOR ENGAGED LEARNING AND HIGH PERFORMANCE TECHNOLOGY

Engaged Learning Indicators	**Practice Scores**	**Policy Scores**
Vision of Learning Responsible for learning Strategic Energized by learning Collaborative		
Tasks Authentic* Challenging* Integrative/Interdisciplinary*		
Assessment Performance-based* Generative Seamless and ongoing Equitable standards		
Instruction/Model Interactive* Generative		
Learning Context Collaborative* Knowledge building Empathetic		
Grouping Heterogeneous* Equitable Flexible		
Teacher Roles Facilitator* Guide Co-Learner/Co-investigator		
Student Roles Explorer* Cognitive apprentice Teacher Producer		
Total Scores		

High Performance Technology Indicators	**Practice Scores**	**Policy Scores**
Access Connectivity Ubiquity Interactivity Design for equitable use		
Operability Interoperability Open architecture Transparency		
Resource Organization Distributed resources User contributions Collab. Projects/Design		
Engagement Opportunities for challenging tasks and experiences Opportunities to learn by doing Guided participation and intelligent tutoring Info just in time and just enough		
Ease of Use Effective helps User friendliness User control Training and support Speed		
Functionality Use of multimedia technologies Use of generic tools Use of context specific tools Programming and authoring skills Design & project skills Use of tools to make tools		

* Indicators provided by Means, et al., 1993

Legend for Table 4a: Current Realities

Scores for Learning Practice are marked on a scale from 0-3

0 = Not in place at this time.
1 = Some users/teachers exploring/piloting/developing.
2 = Many users/teachers have good skills in these areas; practice is effective.
3 = Most users/teachers have mastery, and practice is very widespread; it is a major strength for the school.

Scores for Technology Practice are marked on a scale from 0-3

0 = Not in place at this time.
1 = Some users/teachers have equipment and are exploring/piloting/developing.
2 = Many users/teachers have good computer and technology skills and are actively engaged with the technology.
3 = Most users/teachers have mastered complex technologies (hardware and software) and effective use of technology to promote engaged learning and instruction is a major strength in the school or district.

Policy Scores refer to what the school/community values for a given indicator. This value must be shown in some kind of policy such as a mission statement, a curriculum framework, an assessment system, building organization policy, or a design or plan that has been accepted.

0 = not in place
1 = not so important
2 = somewhat important
3 = very important

TABLE 5: FUTURE GOALS

FOR ENGAGED LEARNING AND HIGH PERFORMANCE TECHNOLOGY

Engaged Learning Indicators	Practice Scores	Policy Scores
Vision of Learning		
Responsible for learning	3**	
Strategic		
Energized by learning		
Collaborative	2	1
Tasks		
Authentic*	2	
Challenging*	2	2
Integrative/Interdisciplinary*		
Assessment		
Performance-based*		
Generative	1	1
Seamless and ongoing	2	1
Equitable standards		
Instruction/Model		
Interactive*	1	
Generative	1	
Learning Context		
Collaborative*	1	
Knowledge building	1	
Empathetic	1	
Grouping		
Heterogeneous*		
Equitable	1	
Flexible	1	
Teacher Roles		
Facilitator*		
Guide	1	
Co-Learner/Co-investigator		
Student Roles		
Explorer*		
Cognitive apprentice		
Teacher	1	
Producer	1	
Total Scores	22	5

High Performance Technology Indicators	Practice Scores	Policy Scores
Access		
Connectivity		
Ubiquity		
Interactivity		
Design for equitable use		
Operability		
Interoperability		
Open architecture		
Transparency		
Resource Location & Dir.		
Distributed resources		
User contributions		
Collab. Projects/Design		
Engagement		
Opportunities for challenging tasks and experiences		
Opportunities to learn by doing		
Guided participation and intelligent tutoring		
Info just in time and just enough		
Ease of Use		
Effective helps		
User friendliness		
User control		
Training and support		
Speed		
Functionality		
Use of multimedia technologies		
Use of generic tools	1	
Use of context specific tools	2	
Programming and authoring skills	1	
Design and project skills	2	
Use of tools to make tools	1	
	7	0

* Indicators provided by Means, et al., 1993

** All data are hypothetical.

Legend for Table 5: Future Goals

Explanation for Scoring: Some Hypothetical Examples for Learning Indicators

Consider the indicators for **Vision of Learning** in Table 4 for Current Realities for our hypothetical school. Strategic was scored at 3 in Policy and Practice Scores, so this indicator probably should not be a priority for future goals. However, Energized by learning was scored at 2 for Practice and 1 for Policy, so it is a possibility for future growth. Similarly, Responsibility and Collaborative were given relatively low scores in Practice and to some extent in Policy.

Which **Vision of Learning** indicator should get priority in Table 5, Future Goals? Referring back to Table 4, staff are most concerned about the discrepancy between the Policy Score of 2 for Responsible for learning and the Practice Score of 0, an important imbalance. Further, they feel if they develop Collaborative practices, it will generate much Energy for learning. Accordingly, for Table 5, Future Goals, the school is given a Practice Score of 3 for Responsible for learning, and a Practice Score of 2 for Collaborative. Since Policy Scores are already high for Responsible for learning and Strategic, they decide to put a small emphasis on incorporating collaborative into a school Policy, so they score it 1.

For **Tasks** in Table 4 for Current Realities, staff noticed another discrepancy: Authentic tasks are valued at 3 in terms of Policy, but Practice was scored at 1. Moreover, there was a lot of emphasis on the need for tasks to be Challenging in this document. Clearly, the school's Practice and Policy Scores reflect their capacity for Integrative/Interdisciplinary, so there is no need to focus on that for the future.

After much thought about the importance of **Tasks** that are Authentic and Challenging, they decide to put a lot of energy into building this capacity. So for Table 5, under the **Tasks** category, they give a Practice Score of 2 for Authentic and Challenging practices and a Policy Score of 2 for Challenging tasks. They think these policies and practices will drive many improvements in **Assessment, Instructional Model, Teacher Roles** and **Student Roles**, so they feel that they want to concentrate their Future Goals on these indicators.

Explanation for Scoring: Some Hypothetical Examples for Technology Indicators

This hypothetical school has a lot of Policies in place as plans, mission statements, and belief statements. They also have a lot in place for all the Technology Indicators. So they decide that they will invest only in developing the Functionality category. Thus, they add 1 for the Use of generic tools; 2 to the Use of context-specific Tools; 1 for Programming; 2 for Design and project skills; and 1 for Use of tools to make tools: a total of 7 points in the Practice column. They would like to have a parallel in Policy for this Indicator, but the school is awaiting important legislation on School-to-Work Policies, so they want to wait until they know more about that legislation before they develop new policies for the school. Thus, they will not be doing any development in Technology Policy at this time.

TABLE 5a: FUTURE GOALS

FOR ENGAGED LEARNING AND HIGH PERFORMANCE TECHNOLOGY

Engaged Learning Indicators	Practice Scores	Policy Scores
Vision of Learning Responsible for learning Strategic Energized by learning Collaborative		
Tasks Authentic* Challenging* Integrative/Interdisciplinary*		
Assessment Performance-based* Generative Seamless and ongoing Equitable standards		
Instruction/Model Interactive* Generative		
Learning Context Collaborative* Knowledge building Empathetic		
Grouping Heterogeneous* Equitable Flexible		
Teacher Roles Facilitator* Guide Co-Learner/Co-investigator		
Student Roles Explorer* Cognitive apprentice Teacher Producer		
Total Scores		

High Performance Technology Indicators	Practice Scores	Policy Scores
Access Connectivity Ubiquity Interactivity Design for equitable use		
Operability Interoperability Open architecture Transparency		
Resource Organization Distributed resources User contributions Collab. Projects/Design		
Engagement Opportunities for challenging tasks and experiences Opportunities to learn by doing Guided participation and intelligent tutoring Info just in time and just enough		
Ease of Use Effective helps User friendliness User control Training and support Speed		
Functionality Use of multimedia technologies Use of generic tools Use of context specific tools Programming and authoring skills Develops design & project skills Use of tools to make tools		

* Indicators provided by Means, et al., 1993

Legend for Table 5a: Future Goals

Some general principles for scoring:

--If an Indicator is given a Practice Score of 3 (very important), it is already a major strength, so there is no need for growth for any Indicator scored at 3. Similarly, if an Indicator is given a Policy Score of 3, it should not be a priority for future growth.

--If there is a large discrepancy between Policy and Practice Scores, the school should look at some efforts toward alignment. If the Policy Score of any given Indicator is 3, and the Practice Score is 0, it would be important to flag that Practice Score by scoring it a 1, 2, or 3 depending on the beliefs and values of the school. Similarly, if a Practice Score is high and a Policy Score is low, the school should consider developing Policies to be in alignment with the Practice in order to maintain training support and administrative support for that Practice.

--If the school's Policy and Practice Scores are higher for **Learning**, compared to **Technology**, or vice versa, these discrepancies should flag attention to the need for development in the area that scored lowest.

The scores in Table 5 are calculated as follows, using the data from Table 4.

1) The big picture for our hypothetical school is determined by looking at Table 4, Current Realities for Policy and Practice. Thus, the user reflects on individual scores for each indicator in Table 4, asking the question: do we want to grow in this area?

2) The user decides if there should be more emphasis or priority on a given indicator for Future Goals.

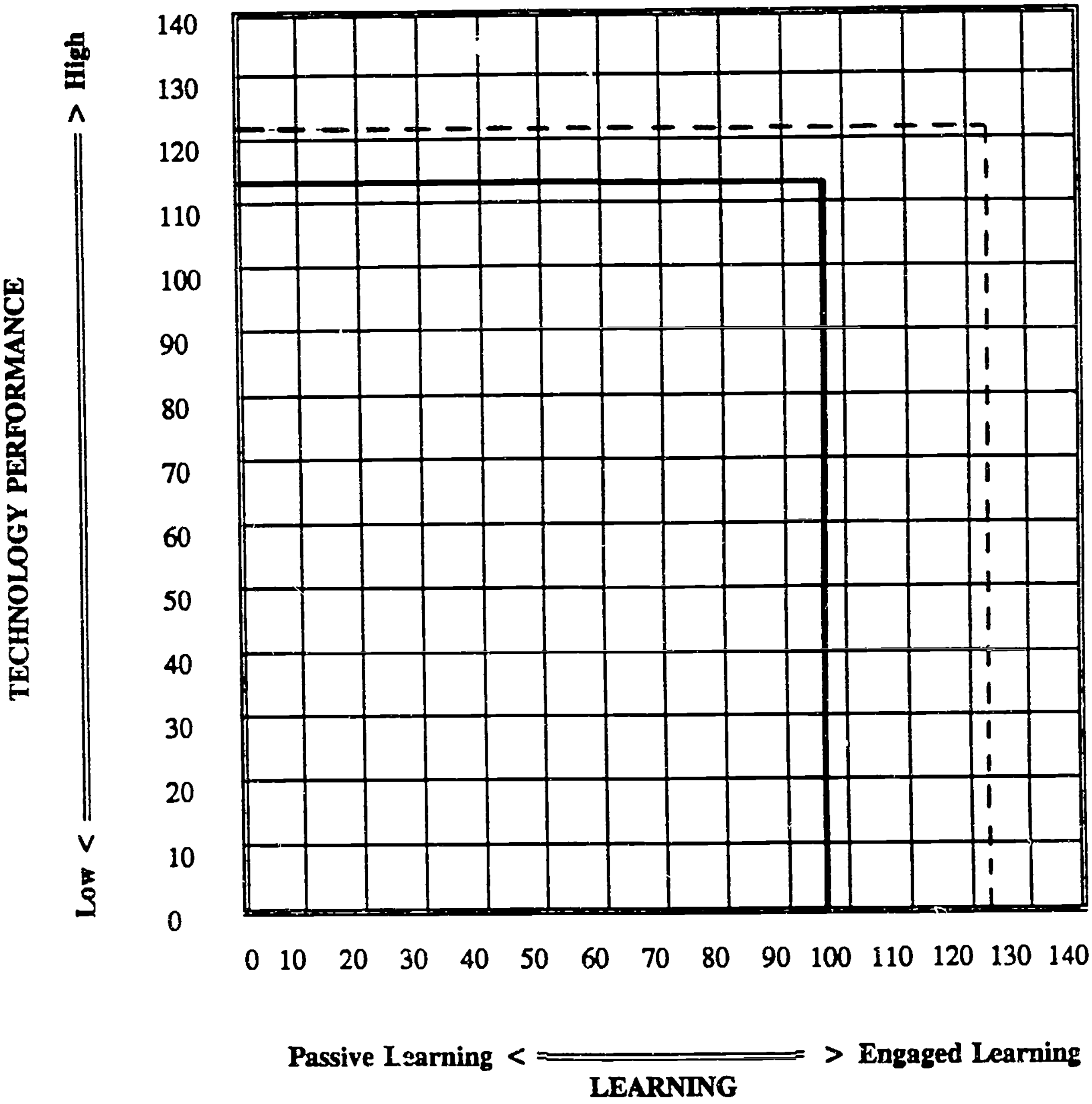
--If not, no additional score or value needs to be added.

--If the school wants to grow in a given area, however, this is shown by adding to Policy and Practice Scores in Table 5.

Clearly, this school is very strong on Policy and less strong on Practice. This is revealed by the large number of 3s in the Policy Scores column of Table 5, compared to the number of 2s and 1s in the Practice Scores column. So this hypothetical school decides it will focus its energies on making Practice more in alignment with Policy.

TABLE 6

CURRENT REALITIES AND FUTURE GOALS



Current Realities = solid line
Future Goals = dashed line

Legend for Hypothetical Data in Table 6

Calculations for Current Realities Profile from Table 4 for Table 6

Learning Practice Total Score	42
Learning Policy Total Score	+ 55
Learning/Current Realities Grand Total	97

Place a circle on the horizontal axis for at about 97.

Technology Practice Total Score	57
Technology Policy Total Score	+ 57
Technology/Current Realities Grand Total	114

Place an X along the vertical axis at about 114.

To plot the Current Realities profile: Draw a solid line upward from the circle on the horizontal axis (Learning) to intersect with a line to the right from the X on the vertical axis (Technology).

Calculations for Future Goals Profile from Table 5 for Table 6

Learning Practice Total Score	22
Learning Policy Total Score	+ 5
Learning/Future Goals Grand Total	27

Add the Learning Future Goals total from Table 5 calculations above to the Learning Current Realities total from Table 4: 97 + 27 = 124. Place a triangle on the horizontal axis at 124.

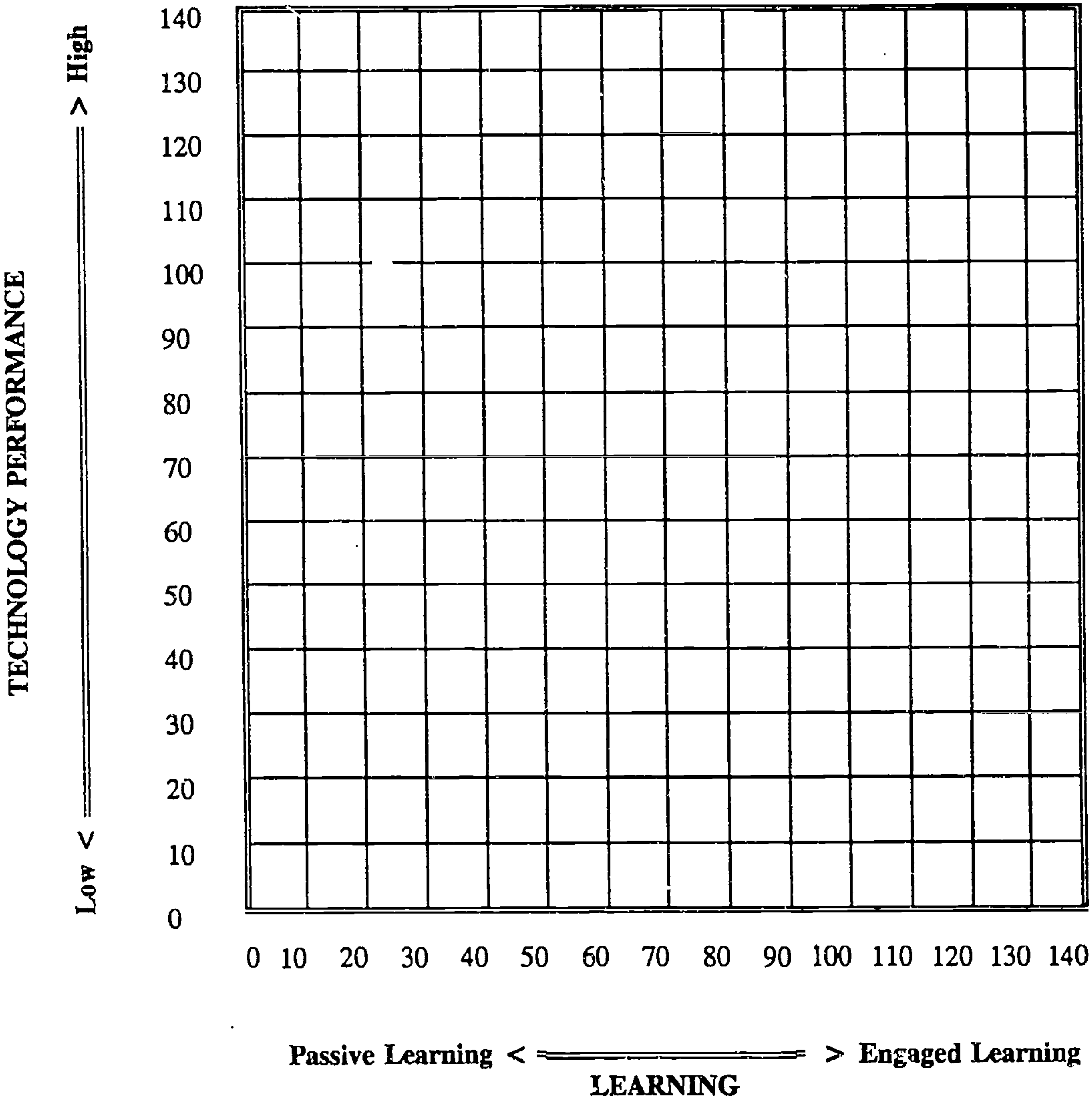
Technology Practice Total Score	7
Technology Policy Total Score	+ 0
Technology/Future Goals Grand Total	7

Add the Technology Future Goals total from Table 5 calculations above to the Technology Current Realities total from Table 4. 114 + 7 = 121. Place a square on the vertical axis at 121.

To plot the Future Goals profile, draw a dashed line upward from the triangle on the horizontal axis (Learning) and to the right from square on the vertical axis (Technology) until they meet.

TABLE 6a

CURRENT REALITIES AND FUTURE GOALS



Current Realities = solid line
Future Goals = dashed line

Legend for Table 6a

Calculations for Current Realities from Table 4a for Table 6a
Learning Practice Total Score
Learning Policy Total Score +

Learning/Current Realities Total

Place a circle on the horizontal axis for the Learning/Current Realities Grand Total Score.

Technology Practice Total Score
Technology Policy Total Score +

Technology/Current Realities Total

Place an X along the vertical axis for the Technology/Current Realities Total Score.

To plot the Current Realities profile: Draw a solid line upward from the circle on the horizontal axis (Learning) to intersect with a line moving to the right from the X on the vertical axis (Technology).

Calculations for Future Goals from Table 5a for Table 6a
Learning Practice Total Score
Learning Policy Total Score +

Learning/Future Goals Grand Total

Add the Learning Future Goals total from Table 5 calculations above to the Learning Current Realities total from Table 4.
_____ + _____ = _____.
Place a triangle on the horizontal axis where the total is.

Technology Practice Score
Technology Policy Score +

Technology/Future Goals Grand Total

Add the Technology Future Goals total from Table 5 calculations above to the Technology Current Realities total from Table 4: _____ + _____ = _____.
Place a square on the vertical axis where the total is.

To plot the Future Goals profile: Draw a dashed line upward from the triangle on the horizontal axis (Learning) to intersect with a line moving to the right from the square on the vertical axis (Technology).

APPENDIX C: COMPARING TECHNOLOGY PROGRAMS

The Tables in this Appendix are to compare two technologies or technology-enhanced programs. Users could be school staff seeking to compare how two programs would rate in terms of promoting the learning and technology features listed in Table 7. The scores for each indicator would be drawn from the descriptive or promotional literature. First the user completes Table 7 and then uses these scores to plot profiles in Table 8.

TABLE 7: COMPARING TECHNOLOGY PROGRAMS

FOR ENGAGED LEARNING AND HIGH PERFORMANCE TECHNOLOGY

Engaged Learning Indicators	Program A Scores		Program B Scores	
	Dsgn	Prtc	Dsgn	Prtc
Vision of Learning				
Responsible for learning	1**	1	3	2
Strategic	0	0	2	1
Energized by learning	0	0	3	3
Collaborative	2	1	3	3
Tasks				
Authentic*	1	0	3	3
Challenging*	2	0	3	3
Integrative/Interdisciplinary*	2	2	3	3
Assessment				
Performance-based*	0	0	2	1
Generative	0	0	3	3
Seamless and ongoing	1	0	3	1
Equitable standards	0	0	2	1
Instruction/Model				
Interactive*	2	0	3	2
Generative	0	1	2	1
Learning Context				
Collaborative*	2	2	3	3
Knowledge building	0	0	2	1
Empathetic	0	0	3	1
Grouping				
Heterogeneous*	3	1	1	1
Equitable	3	0	1	1
Flexible	3	1	3	3
Teacher Roles				
Facilitator*	3	1	3	3
Guide	2	1	3	1
Co-Learner/Co-investigator	0	0	1	1
Student Roles				
Explorer*	3	1	3	3
Cognitive apprentice	0	0	1	
Teacher	3	0	2	1
Producer	3	0	3	3
Totals for Design & Practice	36	12	64	49

High Performance Technology Indicators	Program A Scores		Program B Scores	
	Dsgn	Prtc	Dsgn	Prtc
Access				
Connectivity	1	1	3	2
Ubiquity	3	3	3	1
Interactivity	3	3	3	3
Design for equitable use	3	3	3	1
Operability				
Interoperability	0	0	3	3
Open architecture	0	0	3	3
Transparency	3	3	3	1
Resource Organization				
Distributed resources	0	0	3	2
User contributions	0	0	3	1
Collab. Projects/Design	3	3	3	2
Engagement				
Opportunities for challenging	2	1	3	2
tasks and experiences	-	-	-	-
Opportunities to learn by doing	0	0	1	1
Guided participation and	3	3	3	1
intelligent tutoring	-	-	-	-
Info. just in time and just enough	3	1	2	1
Ease of Use				
Effective helps	3	3	3	1
User friendliness	3	3	3	3
User control	3	1	3	2
Training and support	3	1	2	1
Speed	3	0	3	3
Functionality				
Use of multimedia technologies	0	0	3	3
Use of generic tools	3	1	3	2
Use of context-specific tools	0	0	0	0
Programming and authoring skills	0	0	3	1
Design and project skills	0	0	-	-
Use of tools to make tools	0	0	3	2
	42	30	65	42

* Indicators provided by Means, et al., 1993

** All numbers represent hypothetical scores.

Legend for Table 7: Comparing Technology Program

Des = Design. This column refers to features that are present in the design features as stated in formal descriptions of the program such as articles, profiles, promotional materials.

Prtc = Practice. This column refers to features of the program that are typical in schools and other settings where the program is used. Sometimes there is a discrepancy between what the manual or description says and what the teachers actually do in the classroom. So this tool gives users the opportunity to evaluate the program as it was designed -- its maximal potential-- as well as the program as it is practiced.

Scales for Design Scores for Learning and Technology

0 = Not in place at this time/not applicable
1 = Design definition in place but feature in program falls short of potential stated in the definition
(Example: program has an encyclopedia for student exploration but it is very poor quality.)
2 = Design definition in place and corresponds clearly to one or more features in the program
(Example: program has an encyclopedia and it is functioning as described in literature but is not outstanding.)
3 = Design definition in place and is a major appeal of the program
(Example: Program has an encyclopedia and it is a major strength of the program.)

Scales for Practice Scores for Learning and Technology

0 = Not in place at this time/not applicable
1 = Feature in place with no data to support
2 = Feature clearly in place but only preliminary or limited data available
3 = Strong empirical evidence that this feature of the program is in place and effective.

Rationale for Hypothetical Data in Table 7

Program A in Table 7 is an integrated learning system (ILS). Program B is a computer-driven approach involving integrated multimedia designed from the research from cognitive science. As with any program, both Program A and Program B have higher Design Scores than Practice Scores.

The hypothetical ILS portrayed in Table 7 has strengths in its emphasis on heterogeneous groups and collaborative learning, which is reflected in the Teacher and Student Roles as well as the Vision of Learning. Moreover, it is highly interactive and has a capacity for assessment that is aligned with curriculum and instruction and is ongoing.

The hypothetical Program B in Table 7 was designed to link students to the Internet so that they could engage in co-investigations with students from other schools and with practicing professionals. So this Program has a lot of Access, Operability, and Resource capabilities that Program A does not have, and Program B has higher Learning scores for Design and Practice. Thus, for example, Program B has high scores for all the Access items: Connectivity, Ubiquity, and Interactivity. Similarly, such a program would have high scores for the Operability items: Interoperability, Open Architecture, and Transparency.

TABLE 7a: COMPARING TECHNOLOGY PROGRAMS

FOR ENGAGED LEARNING AND HIGH PERFORMANCE TECHNOLOGY

Engaged Learning Indicators	Program A Scores	Program B Scores
	Dsgn Prtc	Dsgn Prtc
Vision of Learning Responsible for learning Strategic Energized by learning Collaborative		
Tasks Authentic* Challenging* Integrative/Interdisciplinary*		
Assessment Performance-based* Generative Seamless and ongoing Equitable standards		
Instruction/Model Interactive* Generative		
Learning Context Collaborative* Knowledge building Empathetic Multiple perspectives		
Grouping Heterogeneous* Equitable Flexible		
Teacher Roles Facilitator* Guide Co-Learner/Co-investigator		
Student Roles Explorer* Cognitive apprentice Teacher Producer		
Totals for Design & Practice		

High Performance Technology Indicators	Program A Scores	Program B Scores
	Dsgn Prtc	Dsgn Prtc
Access Connectivity Ubiquity Interactivity Design for equitable use		
Operability Interoperability Open architecture Transparency		
Resource Organization Distributed resources User contributions Collab. Projects/Design		
Engagement Opportunities for challenging tasks and experiences Opportunities to learn by doing Guided participation and intelligent tutoring Info. just in time and just enough		
Ease of Use Effective helps User friendliness User control Training and support Speed		
Functionality Use of multimedia technologies Use of basic tools Generic Context specific Develops programming and authoring Develops design & project skills Use of tools to make tools		

* Indicators provided by Means, et al., 1993

** All numbers represent hypothetical scores.

Legend for Table 7a: Comparing Technology Programs

Desn = Design. This column refers to features that are present in the design features as stated in formal descriptions of the program such as articles, profiles, promotional materials.

Prtc = Practice. This column refers to features of the program that are typical in schools and other settings where the program is used. Sometimes there is a discrepancy between what the manual or description says and what the teachers actually do in the classroom. So this tool gives users the opportunity to evaluate the program as is was designed -- its maximal potential-- as well as the program as it is practiced.

Scales for Design Scores for Learning and Technology

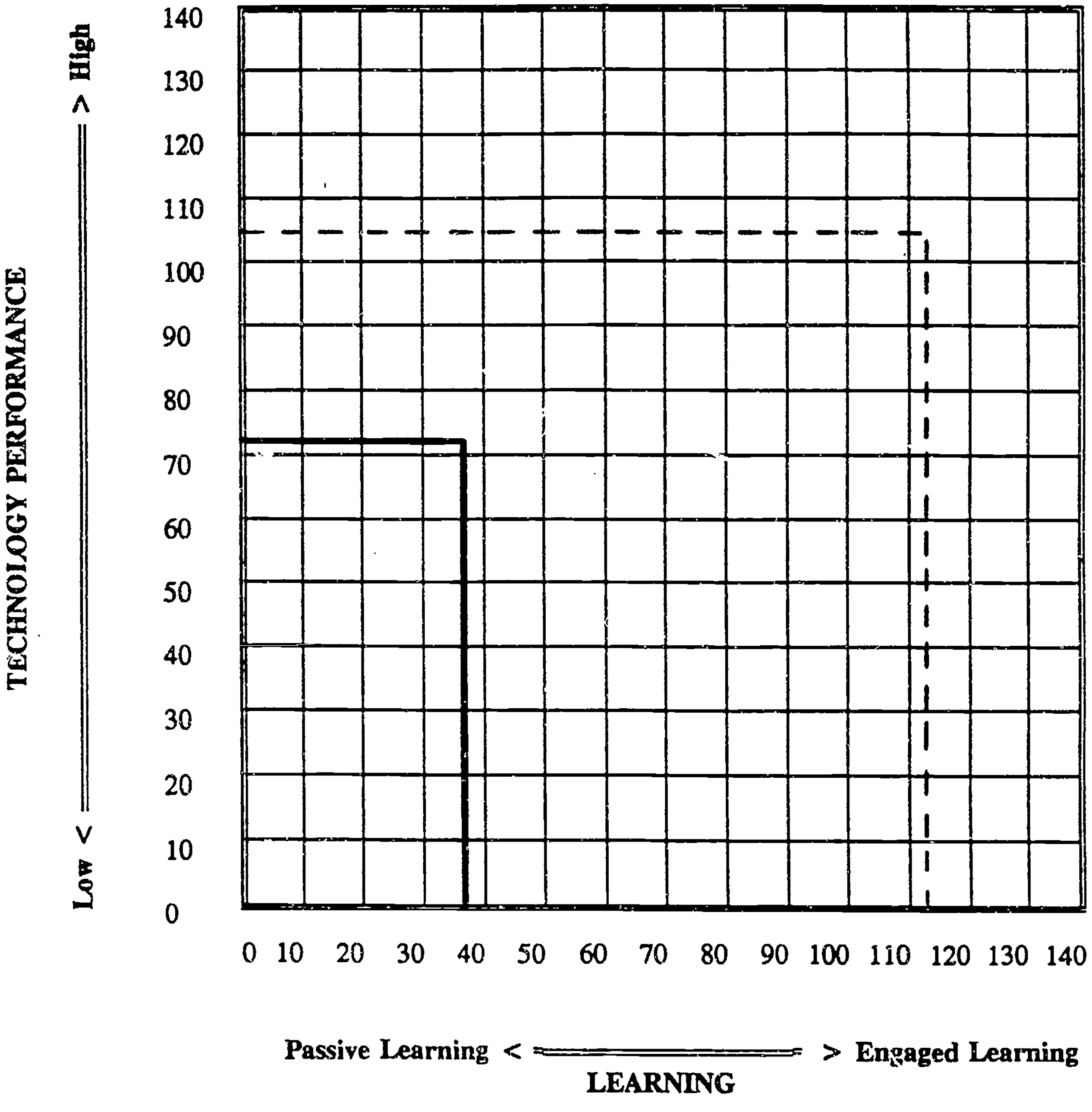
0 = Not in place at this time/not applicable
1 = Design definition in place but feature in program falls short of potential stated in the definition
(Example: program has an encyclopedia for student exploration but it is very poor quality.)
2 = Design definition in place and corresponds clearly to one or more features in the program
(Example: program has an encyclopedia and it is functioning as described in literature but is not outstanding.)
3 = Design definition in place and is a major appeal of the program.
(Example: Program has an encyclopedia and it is a major strength of the program.)

Scales for Practice Scores for Learning and Technology

0 = Not in place at this time/not applicable
1 = Feature in place with no data to support
2 = Feature clearly in place but only preliminary or limited data available
3 = Strong empirical evidence that this feature of the program is in place and effective.

TABLE 8

COMPARING TECHNOLOGY PROGRAMS



Program A = solid line
Program B = dashed line

Legend for Table 8

Calculations for Program A

Using Table 7, column totals, calculate the Learning Grand Total Score:

Program A Learning Design Column Total	36
Program A Learning Practice Column Total	+ 12
Learning Grand Total	48

Place a circle on the horizontal axis at about 48.

Using Table 7 again, calculate the Technology Grand Total Score:

Program A Technology Design Column Total	42
Program A Technology Practice Column Total	+30
Technology Grand Total	72

Place an X on the vertical axis at about 72.

For the full profile of Program A, draw a solid line upward from the circle and sideways from the X to the intersection.

Calculations for Program B

Using Table 7, column totals, calculate the Learning Grand Total Score:

Program B Learning Design Column Total	64
Program B Learning Practice Column Total	+ 49
Learning Grand Total	113

Place a circle on the horizontal axis at about 113.

Using Table 7 again, calculate the Technology Grand Total Score:

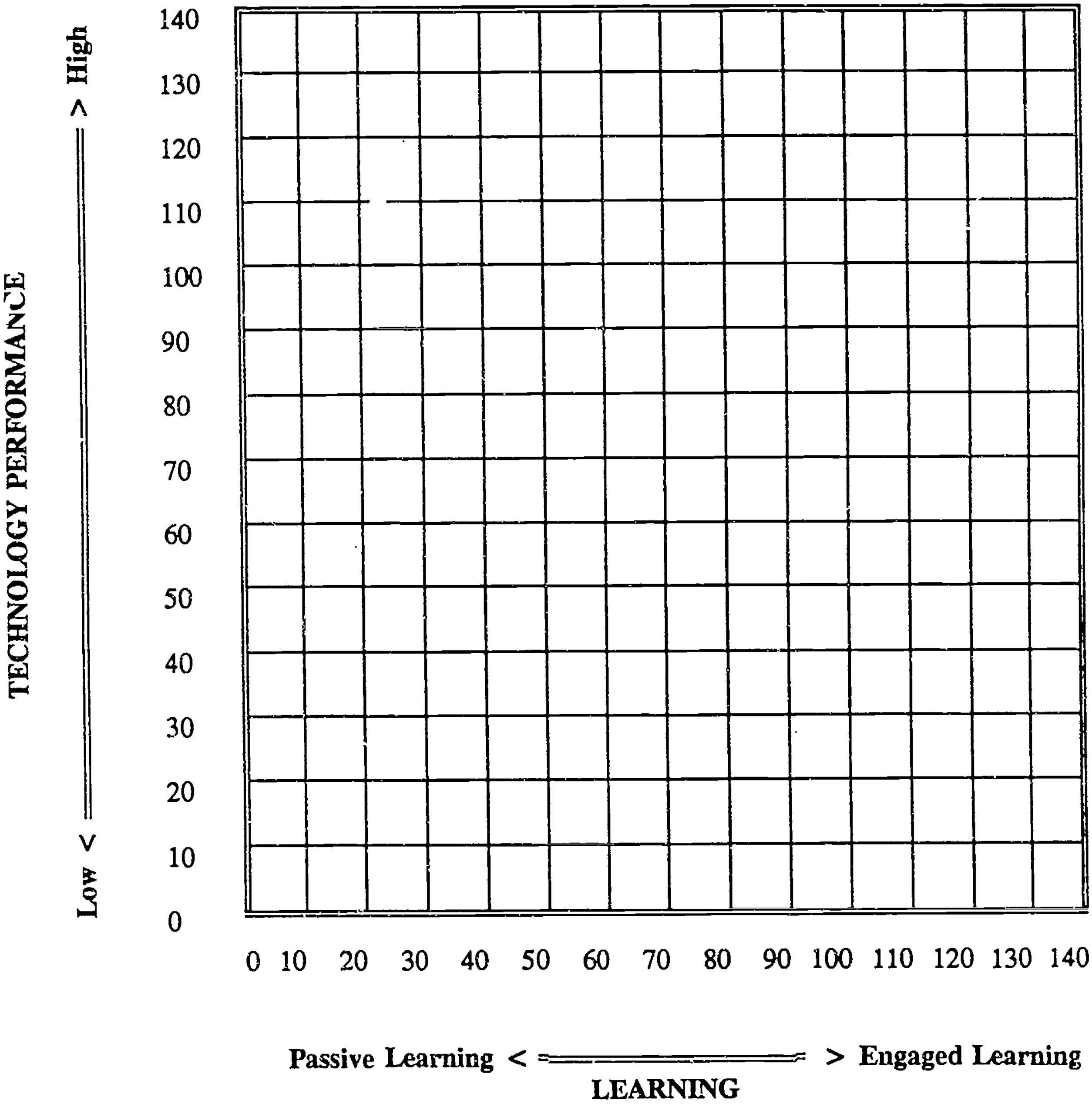
Program B Technology Design Column Total	65
Program B Technology Practice Column Total	+41
Technology Grand Total	106

Place an X on the vertical axis at about 106.

For the full profile of Program B, draw a dashed line upward from the circle and sideways from the X to the intersection.

TABLE 8a

COMPARING TECHNOLOGY PROGRAMS



Program A = solid line
Program B = dashed line

Legend for Table 8a

Calculations for Program A

Using Table 7a., column totals, calculate the Learning Grand Total Score:
Program A Learning Design Column Total
Program A Learning Practice Column Total +

Learning Grand Total
Place a circle on the horizontal axis for the Learning Grand Total for Program A.

Using Table 7a again, calculate the Technology Grand Total Score:
Program A Technology Design Column Total
Program A Technology Practice Column Total +

Technology Grand Total
Place an X on the vertical axis for the Technology Grand Total for Program A.

For the full profile of Program A, draw a solid line upward from the circle and sideways from the X to the intersection.

Calculations for Program B

Using Table 7a, column totals, calculate the Learning Grand Total Score:
Program B Learning Design Column Total
Program B Learning Practice Column Total +

Learning Grand Total

Place a circle on the horizontal axis for the Learning Grand Total for Program B.

Using Table 7a again, calculate the Technology Grand Total Score:
Program B Technology Design Column Total
Program B Technology Practice Column Total +

Technology Grand Total

Place an X on the vertical axis for the Technology Grand Total for Program B.

For the full profile of Program B, draw a dashed line upward from the circle and sideways from the X to the intersection.

APPENDICES D-1 AND D-2: COST CHECKLISTS

D-1: ASSESSING ALL THE COSTS

Instructions: This appendix is provided simply as a tool for the school or district to raise questions for school management to consider as they identify and compare various technologies and programs. Reproduce it and fill it out for various vendors.

Vendor Name______________ USE THIS SPACE FOR NOTES

Actual Costs

- ___Single/Multiple Users

    - ___License
    - ___One-Time Purchase
    - ___Yearly Support Fee
    - ___900 Number
    - ___Upgrade costs

- ___Installation

    - ___Hardware Required
    - ___Supplies (paper, ribbons, etc.)
    - ___Telecommunications
        - ___Lines
        - ___Modems
    - ___Connect charges
    - ___Long distance charges

- ___Training

    - ___Students
    - ___Teachers
    - ___Technicians
    - ___Other

- ___Security

    - ___Building
    - ___Information
    - ___System operations
    - ___Data
- ___Insurance increases

- ___Processing

  ___Disc size
  ___Alternative storage
  ___Alternative power
___CD-ROM
  ___Tapes
  ___Future expansion
  ___Connectivity
  ___Backups
  ___Expansion boards

___Video Production

  ___Cameras
  ___Monitors
  ___Video editing equipment
  ___Laserdisc player
  ___Jukebox
  ___CD-ROM player
  ___Headphones and/or speakers
  ___Audioboard
  ___Software

___Building Requirements

  ___Heating and cooling
  ___Cabling plant
  ___"Clean power" (uninterrupted power)
  ___Inter-Campus Communications

___Special Needs

  ___Delivers to special populations (e.g., deaf/blind)
  ___Delivers to special locations (e.g., rural/hospitals)

Disclosure about Costs

___Purchase costs

  ___Software
  ___Hardware
  ___Installation time
  ___Professional development
___Maintenance Costs

  ___Expenses
  ___Time
  ___Equipment
  ___Materials

___Warranties and Guarantees

___Upgrading Costs

___Possible reentry of data
___Material costs
___Hardware and software
___Legacy hard, soft, data

___Growth Capabilities, Extendibility, Upgrades

___Hardware
___Software
___Ability to import existing data into upgraded version
___Ability to automate or charge software functions to meet unique needs
___Ability to do macros, customized menus, user-selected defaults, etc.
___Ability to add powerful telecommunications such as 56K lines, Integrated Services Digital Network (ISDN), T1 and T3 lines

___Economy of Use

___Site licenses
___Large data sets easily downloaded during off hours
___Telecommunications software allows composition and reading on site rather than online
___Effective dissemination regarding software and free resources
___Support
___Quick, up to speed

APPENDIX D-2: VENDOR QUALITY

Instructions: This appendix is provided simply as a tool for the school or district to raise questions for school management to consider as they identify and compare various technologies and programs. Reproduce it and fill it out for various vendors.

Vendor Name_______________ **USE THIS SPACE FOR NOTES**

___Stability of Software Vendor

- ___Size of vendor
- ___Years in business
- ___Reputation

___Product Line

- ___One-product company
- ___Many products
- ___Research-based
- ___Focus on Learning and student control (vs. teaching)

___Support Staff

- ___Number available
- ___Experience
- ___Knowledge about research on learning
- ___Willingness to go beyond duty
- ___Willingness to provide evidence of successful learning

___Supporting Evidence

- ___Studies and literature focused on learning
- ___Studies conducted by company
- ___Studies conducted by external evaluator
- ___Diversity of data sources
- ___Citations/Reviews in the research literature

___Alignment with Legacy Software and Equipment

Instructions: This appendix is provided simply as a tool for the school or district to raise questions for school management to consider as they identify and compare various technologies and programs.

Vendor B **USE THIS SPACE FOR NOTES**

___Stability of Software Vendor

- ___Size of vendor
- ___Years in business
- ___Reputation

___Product Line

- ___One-product company
- ___Many products
- ___Research-based
- ___Focus on Learning and student control (vs. teaching)

___Support Staff

- ___Number available
- ___Experience
- ___Knowledge about research on learning
- ___Willingness to go beyond duty
- ___Willingness to provide evidence of successful learning

___Supporting Evidence

- ___Studies and literature focused on learning
- ___Studies conducted by company
- ___Studies conducted by external evaluator
- ___Diversity of data sources
- ___Citations/Reviews in the research literature

___Alignment with Legacy Software and Equipment

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