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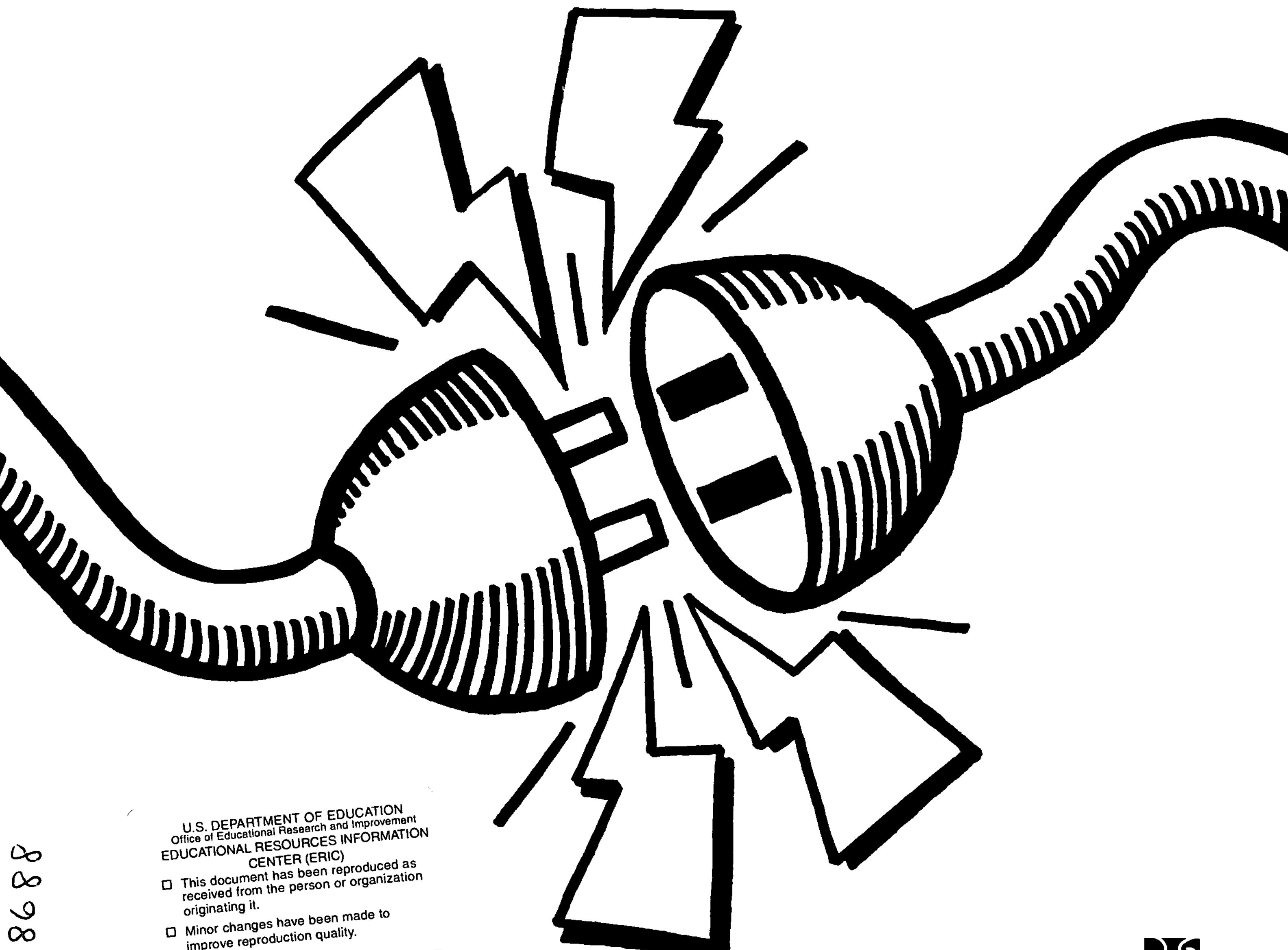
ABSTRACT

This publication is based on work conducted at the North Central Regional Educational Laboratory (NCREL), which serves seven states in the Midwest. Part of the national research and development system administered by the Office of Educational Research and Improvement, U.S. Department of Education, the regional educational laboratories provide schools and communities with the latest information on learning. This planning document is intended for education decision makers to use as they investigate new technologies to support student learning. It explains indicators of effective learning and high technology performance, an analytic framework to help educators ensure that their use of technology complements their goals for student learning, policy issues in the use of technology in learning, and key implementation issues in the use of technology for learning. The publication includes the following sections: "New Times Demand New Ways of Learning"; "The Technology Effectiveness Framework"; "Policy Issues in Using Technology for Engaged Learning"; "Putting Policy into Place"; and "Recommendations for Policymakers and Educators." A section with instructions for using the learning and technology framework includes tables for planners to graphically depict current realities and future goals, and a step-by-step guide to examining technology programs according to features that contribute to engaged learning and high technology performance. (SWC)

Plugging In

choosing and using educational technology



Plugging In

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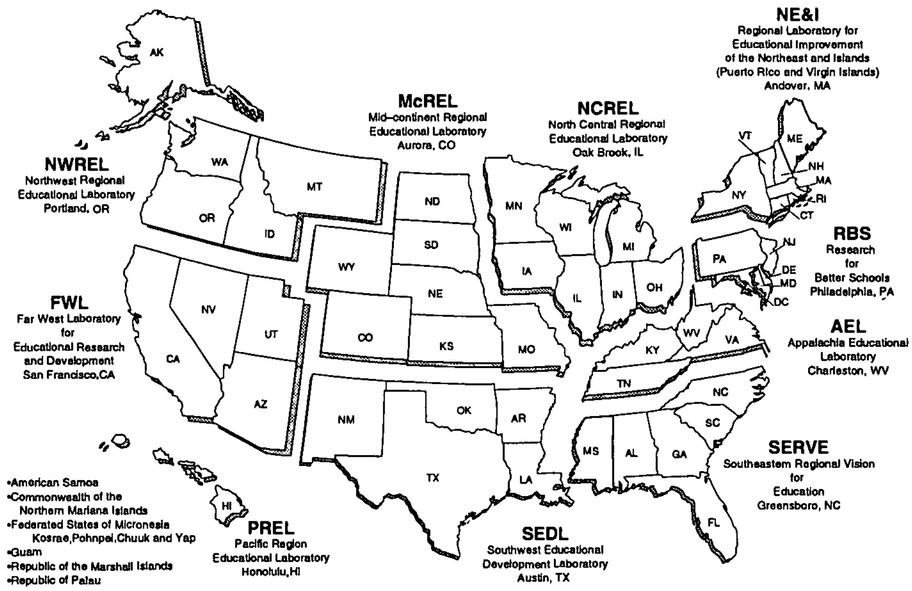

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Preface

The regional educational laboratories provide schools and communities with the latest information on learning. Now the laboratories are examining how various educational technologies can increase teacher effectiveness and improve student achievement. This publication emerged out of those efforts. It is a planning document for education decision makers to use as they investigate new technologies to support student learning.

The Council for Educational Development and Research (CEDaR) established the *EdTalk* publication series to inform policymakers, educators, and local community leaders about significant topics in education. Over the next decade, there is hardly a topic that promises to have more influence on how we educate children than the use of technology in schools.

Plugging In: Choosing and Using Educational Technology introduces what we know about effective learning and effective technology, and puts it together in a planning framework for educators and policymakers. After reading about effective learning and technology, educators can follow the instructions in the yellow section to actually use the framework to plan technology and technology-enhanced programs that complement learning. The publication closes by proposing ways that policymakers can encourage the spread of effective technologies to more schools.

This document reflects a clear point of view. We believe that technology that does not advance students' learning has little value in the classroom. Technology used in conjunction with the most recent research and development findings on learning, however, can help all students achieve in school.

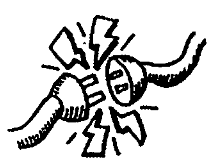
The publication is based on work conducted at the North Central Regional Educational Laboratory (NCREL), which serves seven states in the Midwest. It pulls together the latest information on how students learn best and guides educators to those technologies that are most useful in promoting learning. NCREL welcomes inquiries.

The regional educational laboratories are part of the national research and development system administered by the Office of Educational Research and Improvement, U.S. Department of Education.

Introduction

Compact discs and CD-ROMs. Hypertext. The Internet. Videodiscs. Microcomputer-based laboratories. Virtual reality. Local and wide area networks. Instructional software. Macs, PCs, laptops, notebooks. Educational television. Voice mail and e-mail. Satellite communication. VCRs. Cable TV. Interactive video.

The list of "hot" technologies flowing into the country's school systems goes on and on. The technologies are powerful, exciting, readily available, and increasingly affordable. A recent Department of Education report notes, "Support for the use of technology to promote fundamental school reform appears to be reaching a new high."



Engaged learners are:

- responsible for their own learning
- energized by learning
- strategic
- collaborative

Technology is being used in education as a tool for learning, collaboration, curriculum development, and staff development. But how do we know that we're making the best use of technology? How can we be sure that we're using technology to support what we know about how students learn best? How can we make sure that technology supports *engaged learning*?

The only real measure of the effectiveness of technologies and technology-enhanced educational programs is the extent to which they promote and support students' engaged learning and collaboration.

Using technology for learning

Issues of learning and technology are more critical today than ever before. To meet new challenges, educational decision makers need information about technology — its cost effectiveness, how it delivers information, and its accessibility.

- Technologies are still very expensive. Decision makers must understand differences in cost, capabilities, use, and effectiveness among various technologies and technology-based programs in order to spend their limited dollars wisely.

- Technology changes how information and resources get to schools and other agencies. Electronic publishing allows many different kinds of information providers to serve schools. Printed textbooks may no longer be schools' primary sources of content. This reconfiguration must be planned with our learning goals for students as the top priority.

- Access to technology and technology-enhanced programs must be equitable, and not promulgate and extend differences in educational quality among schools. Decision makers must ensure that poor schools, especially those with students who are academically at risk, have the same opportunities to access and use technologies as schools that are financially better off.

Most evaluations of the effectiveness of technology focus on the technology itself — its costs, its complexity, and its feasibility in particular circumstances. They don't examine the effectiveness of technology as a *tool for learning*. This *EdTalk* offers a way to evaluate the effectiveness of various technologies and technology programs against the backdrop of new research on learning. It presents an analytic framework to help educators ensure that their use of technology complements their goals for student learning.

"Learning" here does not mean how well students perform on standardized tests. That's not learning, as researchers and educational reformers are coming to understand it. There's a dynamic shift occurring in this country as we move from traditional definitions of learning and course design to models of *engaged learning* that involve more student interaction, more connections among schools, more collaboration among teachers and students, more involvement of teachers as facilitators, and more emphasis on technology as a tool for learning. It is in this context that our framework operates; it is this type of engaged learning that technology must support to be effective.

"Learning," as defined here, is not about how well students perform on standardized tests.

This *EdTalk* explains:

- indicators of effective learning and high technology performance
- the framework and its use
- policy issues in the use of technology in learning
- key implementation issues in the use of technology for learning

We conclude with a list of recommendations about effectively using technology for learning.

New Times Demand New Ways of Learning

Recent research builds a powerful case against what used to be accepted "truths" about learning and technology. First, there is strong evidence that traditional models of learning, traditional definitions of technology effectiveness, and traditional models of the cost effectiveness of technology don't work. In place of these old assumptions, researchers are positing new ways of looking at learning that promote:

- engaged, meaningful learning and collaboration involving challenging and real-life tasks; and
- technology as a tool for learning, communication, and collaboration.

This section details the indicators that educators and policymakers can use to measure the effectiveness of technology in learning.

The traditional learning model is not relevant to real student needs

Today's workplaces and communities — and tomorrow's — have tougher requirements than ever before. They need citizens who can think critically and strategically to solve problems. These individuals must learn in a rapidly changing environment, and build knowledge taken from numerous sources and different perspectives. They must understand systems in diverse contexts, and collaborate locally and around the globe.

Citizens of the 21st century must be able to learn in a rapidly changing environment.

These attributes contrast sharply with the discrete, low-level skills, content, and assessment methods that traditional ways of learning favor. The new workplace requirements for learning are incompatible with instruction that assumes the teacher is the information giver and the student a passive recipient. The new requirements are at odds with testing programs that assess skills that are useful only in school.

The traditional mechanisms for evaluating the effectiveness of technology programs don't work

Traditionally, we have determined the effectiveness of a technology program vis-à-vis a "regular" program by comparing student outcomes on standardized tests. Numerous researchers, however, question the utility of this method. When the North Central Regional Education Laboratory (NCREL) surveyed experts about traditional models of technology effectiveness, respondents said:

- "Effectiveness is not a function of the technology, but rather of the learning environment and the capability to do things one could not do otherwise."
- "Technology in support of outmoded educational systems is counterproductive."
- "[The reliance on] standardized tests is ludicrous... Technology works in a school not because test scores increase, but because technology empowers new solutions."

Similarly, the typical way to determine a technology's cost effectiveness is to compare the costs of the technology-enhanced program against the costs of the traditional program. Some researchers decry this approach, pointing out that such cost analyses assume that we should continue teaching the same things, rather than change with changing times. Additionally, cost-effectiveness data could constrain development of innovative applications of technology.

Why Keep Asking the Same Questions When They Are Not the *Right* Questions?

There are no definitive answers to questions about the effectiveness of technology in boosting student learning, student readiness for workforce skills, teacher productivity, and cost effectiveness. True, some examples of technology *have* shown strong and consistent positive results. But even powerful programs might show *no* effects due to myriad methodological flaws. It would be most unfortunate to reject these because standardized tests showed no significant differences. Instead, measures should evaluate individual technologies against specific learning, collaboration, and communication goals.

Where do we go from here?

What we have learned from these reactions to traditional ways of learning and evaluating technology is that we must change the questions and the processes. Specifically, we must establish a clear vision of learning and goals for a school, district, or other unit. Without this vision, there can be no criteria for evaluating technology effectiveness or costs.

What is effective learning and how can it be measured?

Our framework builds upon a framework developed by Barbara Means of SRI International. Means identified seven variables that, when present in the classroom, indicate that effective teaching and learning are occurring.

These classroom variables are:

- children are engaged in authentic and multidisciplinary tasks
- assessments are based on students' performance of real tasks
- students participate in interactive modes of instruction
- students work collaboratively
- students are grouped heterogeneously
- the teacher is a facilitator in learning
- students learn through exploration

We took these variables and reorganized them into a set of eight categories of learning and instruction: vision of learning, tasks, assessment, instruction, learning context, grouping, teacher roles, and student roles. We then expanded the definitions of Means' variables with information from recent research on learning and instruction and added many new variables. In all, there are 26 variables or 26 indicators of engaged learning. These appear in Table 1.

1. Vision of Learning Indicators. Vision of learning indicators describe the goals of engaged learning. These indicators underlie the philosophy and theme that drive all the other indicators discussed here — tasks, assessment, instruction, learning contexts, grouping, and teacher and student roles. We define engaged learning in terms of four indicators.

In engaged learning settings, 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; have a big picture of how specific activities relate to those goals; develop standards of excellence; and evaluate how well they have achieved their goals. They have alternative routes or strategies for attaining goals — and some strategies for correcting errors and redirecting themselves when their plans do not work. They know their own strengths and weaknesses and know how to deal with them productively and constructively. Engaged learners are also able to shape and manage change.

Engaged learners derive excitement and pleasure from learning.

Engaged learners are *strategic*. They know how to learn and constantly develop and refine their learning and problem-solving strategies. This capacity for learning how to learn includes constructing effective mental models of knowledge even though the information may be very complex and changeable. Strategic learners can apply and transfer knowledge to solve problems creatively. They can make connections at different levels.

Engaged learners become *energized by learning*. They derive excitement and pleasure from learning. Learning is its own motivator and results in a lifelong passion for solving problems, understanding, and taking the next step in their thinking and activities.

Engaged learners are *collaborative*. They value others and work with them skillfully. Collaborative learners understand that learning is social, that they 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. Collaborative learners typically value diversity and multiple perspectives.

2. Task Indicators. In engaged learning, tasks are authentic, challenging, and multi-disciplinary. Tasks are *authentic* when they are important to learners and learners use their knowledge of the subject matter in much the same way that real-life practitioners use that knowledge. Students learn authentic tasks in context, practicing basic and advanced skills together as a means to learning big concepts. In other words, they learn by doing.

Challenging tasks are typically complex and involve sustained amounts of time. They require students to stretch their thinking — and often their social skills. Challenging tasks are authentic in that they are about real-world problems and projects, build on life experiences, require in-depth work, and benefit from frequent collaboration.

Table 1: Indicators of Engaged Learning

Variable	Indicator of Engaged Learning	Indicator Definition
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 and next steps 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
	Multidisciplinary	Involves integrating disciplines to solve problems and address issues
Assessment	Performance-based	Involving a performance or demonstration, usually for a real audience and useful purpose
	Generative	Assessments having meaning for learner; maybe produce information, product, service
	Seamless and ongoing	Assessment is part of instruction and vice versa; students learn during assessment
	Equitable	Assessment is culture fair
Instructional Model	Interactive	Teacher or technology program responsive to student needs, requests (e.g., menu driven)
	Generative	Instruction oriented to constructing meaning; providing meaningful activities/experiences
Learning Context	Collaborative	Instruction conceptualizes students as part of learning community; activities are collaborative
	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
	Empathetic	Learning environment and experiences set up for valuing diversity, multiple perspectives, strengths
Grouping	Heterogeneous	Small groups with persons from different ability levels and backgrounds
	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 a member of different groups; works with different people
Teacher Roles	Facilitator	Engages in negotiation, stimulates and monitors discussion and project work but does not control
	Guide	Helps students to construct their own meaning by modeling, 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 and practicing professionals
Student Roles	Explorer	Students have opportunities to explore new ideas/tools; push the envelope in ideas and research
	Cognitive Apprentice	Learning is situated in relationship with mentor who coaches students to develop ideas and skills that simulate the role of practicing professionals (i.e., engage in real research)
	Teacher	Students encouraged to teach others in formal and informal contexts
	Producer	Students develop products of real use to themselves and others

Multidisciplinary work requires wholly integrated instruction. It blends disciplines into thematic or problem-solving pursuits, usually in the form of projects because most work in real life involves multidisciplinary projects.

3. Assessment Indicators. Assessments that promote engaged learning ask students to demonstrate their knowledge and skills in authentic tasks, projects, or investigations. *Performance-based assessments* are meaningful, challenging experiences that involve planning, development over time, presentations, and debriefings about what students learned. Students should take part as much as possible in planning the unit in which the assessment occurs, the criteria for evaluating the assessment, and various forms of self-assessments such as keeping journals.

Performance-based assessments are also *generative*. Students construct their knowledge and develop real products and services, perform in some way, organize events such as conferences, create artistic works, and the like for an audience that cares.

At its best, performance-based assessment is *seamless and ongoing*. That means that the plans, standards and criteria, products, performances, presentations, and debriefings are all instruction at the same time that they are assessment. And vice versa. Movement from one to the other is transparent to the student. Students generally perceive a well-designed hands-on assessment as a challenging and meaningful learning activity.

Performance-based assessments raise issues of equity and standards. It is critical to have *equitable standards* — ones that apply to all students. Parents and students, as well as teachers, should be familiar with those standards and be able to evaluate the performance of an individual or group against them.

4. Instructional Model Indicators. The most powerful instruction is interactive and generative. *Interactive* instruction actively engages the learner with the resources and learning context to construct new knowledge and skills.

Generative instruction, like generative assessment, brings learners with different perspectives together to produce shared understandings. While learning in traditional instruction is a two-person situation (the teacher and the student), in generative instruction learning is a three-person situation (the teacher, the student, and others). Thus, in generative learning, there is co-construction of knowledge; learning occurs as the result of interactions among the learner, the teacher, and others.

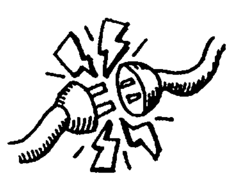
Some Generative Instruction Strategies

Generative approaches to instruction use a wide range of instructional strategies, including:

- Socratic dialogue
- individual and group summarizing
- mechanisms for exploring multiple and differing perspectives
- techniques for building upon prior knowledge
- brainstorming and categorizing
- debriefing
- general and content-specific problem-solving processes
- team teaching
- techniques for constructing mental models and graphic representations

All of these strategies encourage the learner to solve problems actively, conduct meaningful inquiry, reflect, and build a repertoire of effective learning strategies.

5. Learning Context Indicators. Classrooms that foster engaged learning let students learn *collaboratively*. They are *knowledge-building learning communities*. Such communities create *empathetic* learning environments that build on diversity and many perspectives. These features are especially important in classrooms where there are marked differences in students' prior knowledge. In such classrooms, knowledge-building strategies — such as brainstorming — pool the knowledge and experiences of the group, thereby creating more equitable learning conditions for everyone and giving everyone access to the aggregate knowledge.



Focus on Collaboration

Truly collaborative classrooms encourage all students to ask hard questions; define problems; take charge of the conversation when appropriate; participate in setting goals, standards, benchmarks, and assessments; have work-related conversations with various adults in and outside school; and may engage in entrepreneurial activities. This vision contrasts sharply with classrooms in which students respond to questions posed by the teacher. Collaborative classrooms also contrast with cooperative learning settings, which involve highly structured tasks and student roles defined and controlled by the teacher. Collaborative work may be most powerful when it involves flexible, learning-centered investigations that bring students together with practicing professionals and community members. Such collaborations may occur electronically or in work outside the school.

6. Grouping Indicators. Collaborative work that is learning-centered often involves small groups or teams of two or more students within or across classrooms. Although each student's roles and tasks may be different, all members of the group collaborate to accomplish a joint goal or project. When a project is complex or creative, 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 age bring a wealth of knowledge and perspectives to authentic, challenging tasks.

Members of heterogenous groups bring a wealth of knowledge and perspectives to authentic, challenging tasks.

Many teachers use *flexible* grouping, configuring and reconfiguring small groups of students according to specific instructional purposes. This flexibility lets them make frequent use of heterogeneous groups and to form groups according to common interests or needs, usually for short periods of time.

Flexible grouping with recurrent use of heterogeneous groups is one of the most *equitable* means of grouping and assuring that all students have opportunities to learn.

7. Teacher Role Indicators. In classrooms where students engage in learning, teachers are more than information givers. Teachers are *facilitators*, guides, and co-learners. As facilitators, teachers provide rich learning environments, experiences, and activities; create opportunities for students to work collaboratively, to solve problems, do authentic tasks, and share knowledge and responsibility.

Teachers play complex and varied roles as *guides*. They mediate, model, and coach. When mediating student learning, teachers must constantly adjust the level of information and support according to students' needs and help them 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 when needed. As guides, teachers rely heavily on active listening skills and Socratic questioning techniques.

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

8. Student Role Indicators. Students who engage in learning are *explorers*. They discover concepts and connections and apply skills by interacting with the physical world, materials, technology, and other people. Often students jump into an activity with little prior instruction 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.

Discovery-oriented exploration provides students with opportunities to make decisions.

Reflective thinking is also essential for students as *cognitive apprentices*. In cognitive apprenticeships, learning is essentially formative, with daily feedback on many aspects of a complex problem or skill. Learning takes place when students observe, apply, and — through practice — refine their thinking processes so that they increasingly formulate more powerful questions, problems, and solutions, moving toward greater expertise. By reflecting across a diverse range of tasks, students come to identify common elements in their many experiences. This enables them to generalize their skills and transfer their learning to new situations.

For some situations, most often when students must be *teachers*, students need summative learning experiences. These experiences help them to integrate and holistically represent what they have learned intensely over a period of time and to develop the social skills needed to help others learn.

Similarly, students *produce* knowledge. They generate products for themselves and the community that synthesize and integrate knowledge and skills. Through technology, students are increasingly able to contribute to the world's knowledge.

What defines high technology performance and how can it be measured?

There is strong consensus in the research community that technology and technology-enhanced programs can promote engaged learning. Researchers have identified many features of technology that are important to learning. This section presents indicators for identifying effective, high technology performance, organized within six categories:

- *access* that a school has to diverse technologies and resources, both within its own classrooms and beyond the school;
- *operability* of the technology;
- *organization* of the technology in terms of its location and distribution;
- *"engagability,"* or the capacity of the technology to engage students in challenging learning;
- *ease of use*; and
- *functionality*, or the technology's capacity to prepare students to use a variety of technological tools.

For each of these six categories of technology performance, we identified indicators of high performance that would promote engaged learning. Table 2 displays these indicators.

1. **Access Indicators.** Access indicators address how physically accessible technology is to the school. A technology or technology-enhanced program has high access when it has connectivity, ubiquity, and interconnectivity. Further, the technology should be used equitably.

Connectivity refers to the technology's ability to access rich resources within and beyond the school because it is connected to those resources. Connections between a school and a telecommunications source must be in place if the school is to benefit from the wealth of free and low-cost resources on the information highway.

Connections between a school and a telecommunications source must be in place if the school is to benefit from the wealth of resources on the information highway.

In terms of *ubiquity*, the ideal situation would be for all students to have their own networked computer. Since that probably won't be the case anytime in the near future, technology is considered ubiquitous when computers, printers, media technologies, and other equipment are easily and readily available to teachers and students for problem solving, communication, collaboration, and data exchange. Simply having a computer or multimedia lab in every school is not ubiquitous, because students and teachers

Table 2: Indicators of High Technology Performance

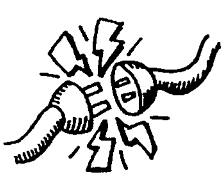
Variable	Indicator of High Technology Performance	Indicator Definition
Access	Connective	Schools are connected to Internet and other resources
	Ubiquitous	Technology resources and equipment are pervasive and conveniently located for individual (as opposed to centralized) use
	Interconnective	Students and teachers interact by communicating and collaborating in diverse ways
	Designed for equitable use	All students have access to rich, challenging learning opportunities and interactive, generative instruction
Operability	Interoperable	Capable of exchanging data easily among diverse formats and technologies
	Open architecture	Allows users to access third-party hardware/software
	Transparent	Users are not — and do not need to be — aware of how the hardware/software operates
Organization	Distributed	Technology/system resources are not centralized, but exist across any number of people, environments, and situations
	Designed for user contributions	Users can provide input/resources to the technology/system on demand
	Designed for collaborative projects	Technology is designed to facilitate communication among users with diverse systems/equipment
Engagability	Access to challenging tasks	Technology offers or allows access to tasks, data, and learning opportunities that stimulate thought and inquiry
	Enables learning by doing	Technology offers access to simulations, goals-based learning, and real-world problems
	Provides guided participation	Technology responds intelligently to user and is able to diagnose and prescribe new learning
Ease of Use	Effective helps	Technology provides help indices that are more than glossaries; may provide procedures for tasks and routines
	User friendliness/user control	Technology facilitates user and is free from overly complex procedures; user can easily access data and tools on demand
	Fast	Technology has a fast processing speed and is not "down" for long periods of time
	Available training and support	Training is readily and conveniently available, as is ongoing support
	Provides just enough information just in time	Techology allows for random access, multiple points of entry, and different levels and types of information
Functionality	Diverse tools	Technology enables access to full diversity of generic and context-specifid tools basic to learning and working in the 21st century
	Media use	Technology provides opportunities to use media technologies
	Promotes programming and authoring	Technology provides tools (e.g., "wizards") that are used to make other tools
	Supports project design skills	Technology facilitates the development of skills related to project design and implementation

have to physically go somewhere and perhaps wait for some length of time before they can use the equipment. Networks of computers and other equipment — especially printers — throughout the school indicate high technology performance.

Interconnectivity occurs when students and teachers communicate and collaborate in diverse ways (exchanging data in different formats and publishing, for example) using technology.

For a school to be connected and interconnected, and for its technology to be ubiquitous, means that everyone has access to the best and most extensive resources the technology has to offer. If a system has home-school connections but no connections to the local library system or to the Internet, or if only students in gifted classes or in magnet schools know how to use those connections effectively, the technology is not being used *equitably*. Technology in schools should be available to all students so that everyone has access to rich and challenging learning opportunities.

2. Operability Indicators. Operability indicators refer to the ease and convenience of using the technology. The first operability indicator, *interoperability*, is the capacity to easily exchange data with, and connect to, other hardware and software. To do so, the technology must have an *open architecture*. This feature allows users to access data using different (third-party) hardware and software. It also lets users modify the system — sometimes dramatically. An example of such a modification is when a user can add his or her own template to a spreadsheet or desktop publishing program. Interoperability also requires *transparency*, which means the capability to move from one format or program to another easily and unobtrusively. More specifically, in transparent systems, the user is not — and does not need to be — aware of the process, procedures, and protocols by which the hardware and software effectively perform their functions.



Operability Indicators and Engaged Learning

Technologies or programs that have open architecture and transparency promote engaged learning because they allow teachers and learners to spend maximum time and energy enjoying and using the resources they access, rather than spending their time and energy on learning how to use the technology and/or performing complex and time-consuming procedures to move from one program or format to another.

3. Organization Indicators. Organization indicators pertain to questions such as: Where is the information stored? How are resources connected? How do new resources get into the system? Is the transmission asymmetrical (from one source *to* another) or symmetrical (having two-way transmission capability)? Who is in charge?

Some schools and technology programs centralize information. Students typically access it by way of limited-capability, "dumb" terminals that connect to mainframes or other centralized servers. In such systems, information flows in one direction only — from the central source to users. The system operator is in charge of what information and resources go into the system, when they are entered and distributed to others, and so on.

The Power — and Limits — of Centralization

Centralized systems are likely to inhibit learning to the extent that they use the transfer model of learning and instruction. This model assumes that the central source holds most of the important information and that it is the student's job to transfer the information from this central source to his or her location and "learn" it.

Such systems may offer rich resources such as a multimedia encyclopedia, or an efficient management system for assessment and record keeping. These centralized systems would, by definition, be high performance. However, this high performance may be very limited. For one thing, learning may not be very engaged because the educational objectives of this one-way transmission are likely to be a low-level focus on basic skills.

In contrast to these centralized and relatively closed resource systems, *distributed* systems are organized very differently. The premise behind distributed systems is that the resources that enable and give shape to learning are spread across many people and places both within the local system and outside it (e.g., the Internet). To this end, systems that provide wide area networks (WANs) allow access to many more resources than do systems that provide only local area networks (LANs).

These networked open systems promote two-way transmissions and *user contributions*, thereby encouraging users to become producers. Any number of users can contribute information, products, and services to a distributed system for others to share. In these systems, the users control when they make a contribution and what that contribution is.

Distributed systems typically feature tools that make it possible for users to take part in *collaborative projects* and co-investigations. On-line conferences and bulletin boards, access to remote files and joint products, and the capability to communicate in real time with other users accessing the same data all promote collaboration. Users can access programs to work in groups, build consensus, brainstorm, outline, develop plans, schedule meetings, monitor programs on group objectives, and develop joint products. All these capabilities help develop knowledge-building communities.

4. Engagability Indicators. This indicator refers to features in a technology's design that promote engaged learning. One such design feature is the technology's capability (e.g., software) to *provide challenging tasks, opportunities, and experiences.* For example, the technology could provide:

- complex problems and cases; links to challenging curricula and unique resource repositories from museums and libraries; opportunities to examine contrasting events or data sets;

- access to experts, peers, community members, and/or other learners who can guide, mentor, tutor, mediate, broker, share, inform, and involve users in learning in productive and meaningful ways;

- access to rich media resources — three-dimensional images, audio, video, virtual reality — for data manipulation and for presentations; and/or

- tools for interactive browsing, searching, and authoring.

A second design feature that enhances engaged learning allows students to *learn by doing.* Tools such as scenarios and simulations provide opportunities to develop expertise using real-world problems and resources. These tools let the user plan, reflect, make decisions, experience the consequences of actions, change direction, and examine alternative solutions and assumptions.

A third design feature that is important to engaged learning is the extent to which the technology provides *guided participation.* Various techniques achieve guided participation:

- Socratic questioning

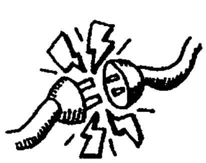
- intelligent tutoring

- diagnosing and guiding the analysis of errors
- adapting the technology or system to respond to student actions

All of these techniques allow users to customize content to suit particular interests or learning styles. Techniques and tools that help students see how practicing professionals and others think also enhance guided instruction. For example, students can use "wizards" — intelligent tools that help users work through a set of complex procedures — embedded questions, prompts, and coaches. These tools provide learners with opportunities to anticipate problems and events.

5. Ease-of-Use Indicators. High performance technology is easy to use. For example, it should provide *effective helps*; these should be informative, clear, comprehensive, readily available, and context-specific. The technology should be *user friendly* (accessible and understandable) and encourage user *control*. This latter attribute 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. The technology should have a *fast* processing speed; it should also provide the user with feedback regarding any system delays. *Training for and supporting technology use* are vital; these services should be available locally as well as be accessible from remote locations.

Finally, the technology should *provide information that is just in time and just enough.* High performance on this indicator means that people with immediate, pressing needs can easily access simplified, useful information, while people who have time for reflection and exploration can access more complex and rich data.



Just in Time, Just Enough with Hypertext

Hypertext is a computer-based text retrieval system that lets users access increasingly more in-depth information about a topic. With hypertext, users point their cursor and "click" on highlighted portions of text to retrieve additional information on that topic. For example, say a user opens a document on school violence and wants to find out more about peer mediation programs. The user simply "clicks" on "peer mediation" in the text and is instantly provided with an almost unlimited supply of additional information on the subject. An example of hypertext is NCREL's *Pathways to School Improvement,* which provides educators and administrators with the latest research on any issue from assessment to professional development. *Pathways* can be accessed at the following Internet address: http://www.ncrel.org/ncrel/sdrs.pathways.htm.

6. Functionality Indicators. High functionality ensures, first, that the technology provides *diverse tools* — generic and context-specific — fundamental to learning and working in the 21st century. These tools begin with "basics" like databases, spreadsheets, and word processing, and move on to such high-level, context-specific tools as sonar for oceanographic research. Another indicator of functionality is the extent to which the technology incorporates *media* such as color printers, video cameras, audio and video recording and editing equipment, and graphics.

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

Functionality also has to do with the technology's capacity 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.

Instructions for Using
The Learning and Technology Framework

EDTALK

The following charts enable school decision makers to use the Technology Effectiveness Framework. Completing them will help you identify your goals in the effective use of technology to increase engaged learning.

Tables I and II cover *Current Realities and Future Goals*. By following the instructions that accompany them, you can graphically depict the learning and technology practices and policies that are in place now in your classroom, school, or district against your vision of learning and technology for the future. This information can help you decide where to invest additional resources or where to strengthen your present school practices and policies.

Table III, *Comparing Technology Programs*, is a step-by-step guide to examining technology programs according to features that contribute to engaged learning and high technology performance.

Tables I and II: Current Realities and Future Goals

You will be using two tables and a grid to compare your current practices and future goals. Table I asks you to reflect on the 26 indicators for engaged learning described in this document, ranking your current and desired practices and policies for each indicator on a scale from 0 through 3. Table II asks you to rank your current and desired practices and policies for each of the 22 indicators of high technology performance.

- *Practice* scores reflect what is actually in place in classrooms and schools now and where you want to see growth.
- *Policy* scores refer to what your school or community thinks is important now and where you think there is a need for more emphasis in the future. For an indicator to be part of current policy, it must appear in some kind of policy document such as a mission statement, curriculum framework, assessment system, building organization plan, or some other plan that has been accepted in a school or community.

Finally, plot your scores on Graph 1. This will show you where your school is now in terms of ideal engaged learning and high technology performance and how close your school's vision of the future is to that ideal.

Completing Table I

Current Realities in Engaged Learning. In the first two boxes next to each engaged learning indicator, score your school's current learning practices and policies. When you have filled in all your scores in the first two columns, add them up and write the totals in the column totals boxes at the bottom.

Engaged Learning Practices

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

Engaged Learning Policies

0 = Not in place
1 = Not so important
2 = Somewhat important
3 = Very important

Future Goals in Engaged Learning. Refer to your scores in the Current Realities boxes to determine your scores for Future Goals. Look for imbalances between your practice scores and your policy scores to identify priorities for future growth. For example, if you marked a 3 in both the policy and practice box of the "responsibility for learning" indicator, students in your school are already achieving this important policy goal and you are better off putting your emphasis elsewhere. A policy score of 3 and a practice score of 0 or 1 on the same indicator clearly shows an imbalance, as does a practice score of 2 and a policy score of 1.

Next, decide how important each imbalance is to improving practice in your school. Fill in the boxes opposite those indicators where you think your school or district should concentrate on growth using the scale below. Do the same thing in the policy column. When you have filled in all of your scores, add them up and write the total in the column totals box.

Future Goals

0 = not a priority for improvement at this time/not being considered
1 = will concentrate on improvement but a low priority
2 = will concentrate on improvement, medium priority
3 = will concentrate on improvement and high priority

Table I: Current Realities & Future Goals in Engaged Learning Practices & Policies

Engaged Learning Indicators	Current Realities		Future Goals	
	Practice	Policy	Practice	Policy
Vision of Learning				
Responsible for learning	____	____	____	____
Strategic	____	____	____	____
Energized by learning	____	____	____	____
Collaborative	____	____	____	____
Tasks				
Authentic	____	____	____	____
Challenging	____	____	____	____
Multidisciplinary	____	____	____	____
Assessment				
Performance-based	____	____	____	____
Generative	____	____	____	____
Seamless and ongoing	____	____	____	____
Equitable	____	____	____	____
Instructional 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	____	____	____	____
Column Totals	____	____	____	____
Grand Totals	____		____	

Completing Table II

Current Realities in High Performance Technology. In the first two boxes opposite each high technology performance indicator, score your school's current technology practices and policies using the scale below. When you have filled in all your scores, add them up and write the totals in the column totals box at the bottom.

High Performance Technology Practice

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 effectively use technology to promote engaged learning; is a major strength in the school or district

High Performance Technology Policies

0 = Not in place
1 = Not so important
2 = Somewhat important
3 = Very important

Future Goals in High Performance Technology. Determine your Future Goals scores for technology practice and policy in the same way you determined Future Goals in Table I. Refer back to the Current Practices columns and identify the imbalances between technology practices and policies. Then decide which imbalances are the most important to bring into alignment. Mark the practice and policy columns of each indicator, using a scale of 1 for low priority and 3 for high priority.

In deciding where to place your technology priorities, also take practicality into account. Be realistic about what your school or district can afford at this time. Also, if your school, district, or state is developing a new technology plan or policy, you may want to put off investing in some areas until you know more about those plans. When you have filled in all your scores, add them up and write the total in the column totals boxes at the bottom.

Table II: Current Realities and Future Goals in High Performance Technology

High Performance Technology Indicators	Current Realities		Future Goals	
	Practice	Policy	Practice	Policy
Access				
Connective	____	____	____	____
Ubiquitous	____	____	____	____
Interconnective	____	____	____	____
Designed for equitable use	____	____	____	____
Operability				
Interoperable	____	____	____	____
Open architecture	____	____	____	____
Transparent	____	____	____	____
Organization				
Distributed	____	____	____	____
Designed for user contributions	____	____	____	____
Designed for collaborative projects	____	____	____	____
Engagability				
Access to challenging tasks	____	____	____	____
Enables learning by doing	____	____	____	____
Provides guided participation	____	____	____	____
Ease of Use				
Effective helps	____	____	____	____
User friendliness/user control	____	____	____	____
Fast	____	____	____	____
Available training and support	____	____	____	____
Provides just enough information just in time	____	____	____	____
Functionality				
Diverse tools	____	____	____	____
Media use	____	____	____	____
Promotes programming and authoring	____	____	____	____
Supports project design skills	____	____	____	____
Column Totals	____	____	____	____
Grand Totals	____		____	

Plotting Graph 1

Plotting Current Realities. Add your Current Realities *practice* and *policy* scores for *engaged learning* and enter the total in the Grand Totals box. Draw a solid vertical line on the horizontal learning axis to indicate the grand total. Then add your Current Realities *practice* and *policy* scores for *technology performance* and enter the total in the Grand Totals box. Draw a solid horizontal line on the vertical technology performance axis to indicate the grand total.

Mark the intersection of the horizontal and vertical solid lines as point A. This indicates where your school or district is currently with regard to using high performance technology to enhance engaged learning.

Plotting Future Goals. Add your Future Goals *policy* and *practice* scores for *engaged learning* and enter the total in the Grand Totals box. Then add the Future Goals grand total to the Current Realities grand total for engaged learning and draw a vertical dashed line on the horizontal learning axis to indicate the new total.

Add your Future Goals *policy* and *practice* scores for *technology performance* and enter the total in the Grand Totals box. Then add the Future Goals grand total to the Current Realities grand total for technology performance and draw a dashed horizontal line on the vertical technology performance axis to indicate the grand total.

Mark the intersection of the two dashed lines as point B. This indicates where your school or district will be with regard to using high performance technology to enhance learning if you were to implement your desired goals.

Notice which quadrant your two intersections fall into. Point A indicates whether your current practices and policies are at the high end of engaged learning and high technology performance (Quadrant A) or at the low end (Quadrant D). Or perhaps they are somewhere in between (Quadrants B or C). Point B tells you where your school or district's goals fall in relation to the ideal of high engaged learning and high technology performance.

Graph 1: Current Realities and Future Goals

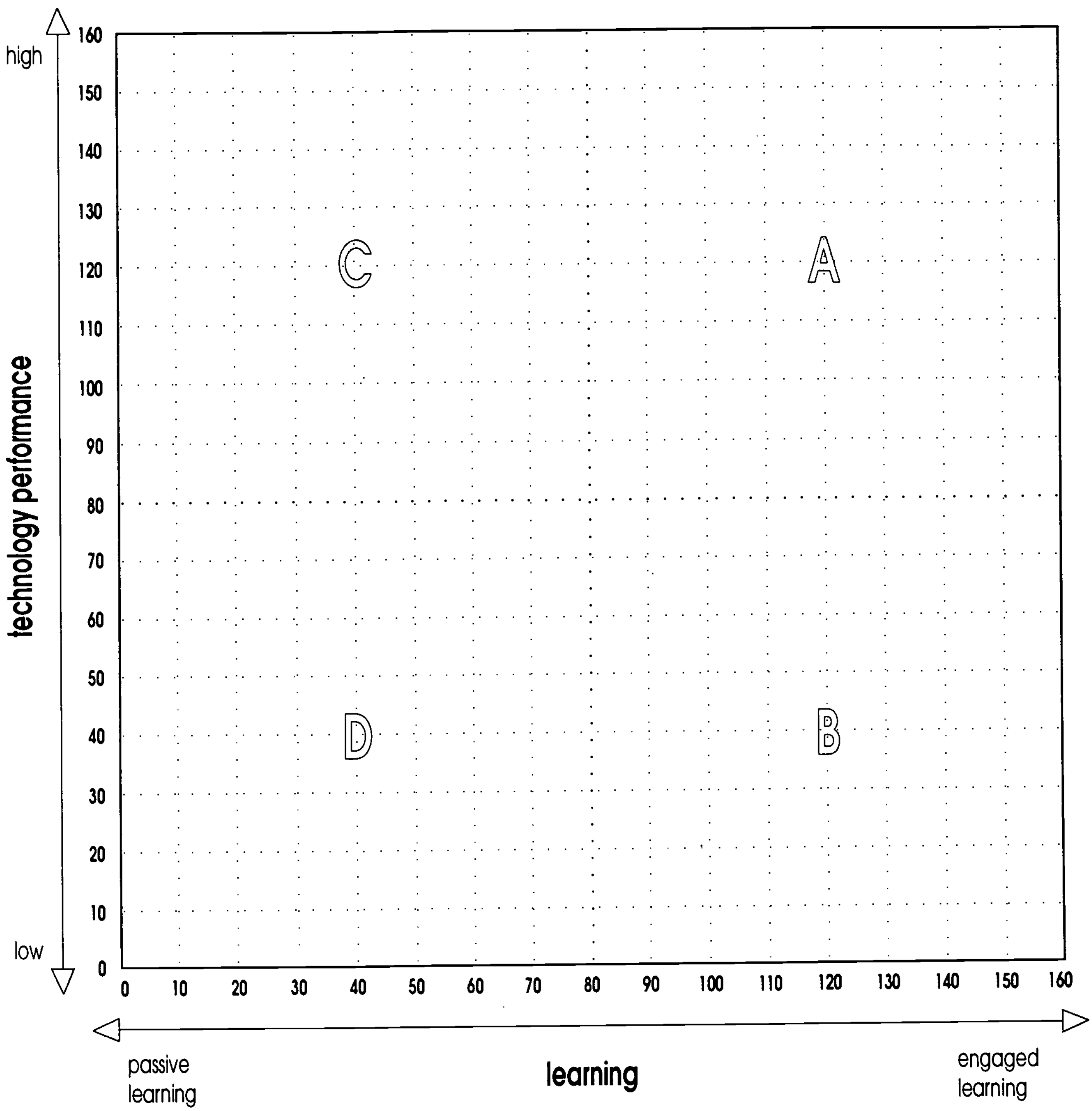


Table III: Comparing Technology Programs

The table in this section helps you compare technology and technology-enhanced programs in promoting engaged learning. You will be able to evaluate programs as they were designed and as they actually perform in practice. First, complete the two charts in Table III — one for engaged learning indicators (chart 1) and one for high performance technology indicators (chart 2) — and then use your scores to plot the program profiles in Graph 2.

For each program, you will be placing two numbers opposite each indicator in each chart. The first number refers to features that are present in the design of the technology or technology-enhanced program, as stated in formal descriptions of the program such as articles, profiles, and promotional materials. Place this number in the Design column for each indicator in each chart.

Sometimes there is a discrepancy between what the manual or description says about a given technology or program and what teachers who actually use it say it does. The second column, marked Practice, allows you to evaluate this aspect of the technology. To fill in this column, you will need to talk to teachers who have used the technology in the classroom or attend demonstrations of the technology. Place this number in the Practice column for each indicator in each chart.

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 (e.g., program has an encyclopedia for students to explore but it is of very poor quality)
2 = Design definition in place and corresponds clearly to one or more features in the program (e.g., program has an encyclopedia and it is functioning as described in literature but it is not outstanding)
3 = Design definition in place and is a major appeal of the program (e.g., program has an encyclopedia and it is a major strength of the program)

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

When you have filled in all your scores, add each column and write the total for each at the bottom of the column. You are now ready to compare the two programs on the graph.

Table III: Comparing Technology Programs

Chart 1

Engaged Learning Indicators	Program A		Program B	
	Design	Practice	Design	Practice
Vision of Learning				
Responsible for learning	___	___	___	___
Strategic	___	___	___	___
Energized by learning	___	___	___	___
Collaborative	___	___	___	___
Tasks				
Authentic	___	___	___	___
Challenging	___	___	___	___
Multidisciplinary	___	___	___	___
Assessment				
Performance-based	___	___	___	___
Generative	___	___	___	___
Seamless and ongoing	___	___	___	___
Equitable	___	___	___	___
Instructional 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	___	___	___	___
Column Totals	___	___	___	___
Grand Totals	___		___	

Chart 2

High Performance Technology Indicators	Program A		Program B	
	Design	Practice	Design	Practice
Access				
Connective	___	___	___	___
Ubiquitous	___	___	___	___
Interconnective	___	___	___	___
Designed for equitable use	___	___	___	___
Operability				
Interoperable	___	___	___	___
Open architecture	___	___	___	___
Transparent	___	___	___	___
Organization				
Distributed	___	___	___	___
User contributions	___	___	___	___
Collaborative projects	___	___	___	___
Engagability				
Access to challenging tasks	___	___	___	___
Enables learning by doing	___	___	___	___
Guided participation	___	___	___	___
Ease of Use				
Effective helps	___	___	___	___
User friendliness/control	___	___	___	___
Fast	___	___	___	___
Available training & support	___	___	___	___
Provides just enough information just in time	___	___	___	___
Functionality				
Diverse tools	___	___	___	___
Media use	___	___	___	___
Promotes programming and authoring	___	___	___	___
Supports project design skills	___	___	___	___
Column Totals	___	___	___	___
Grand Totals	___		___	

Plotting Graph 2

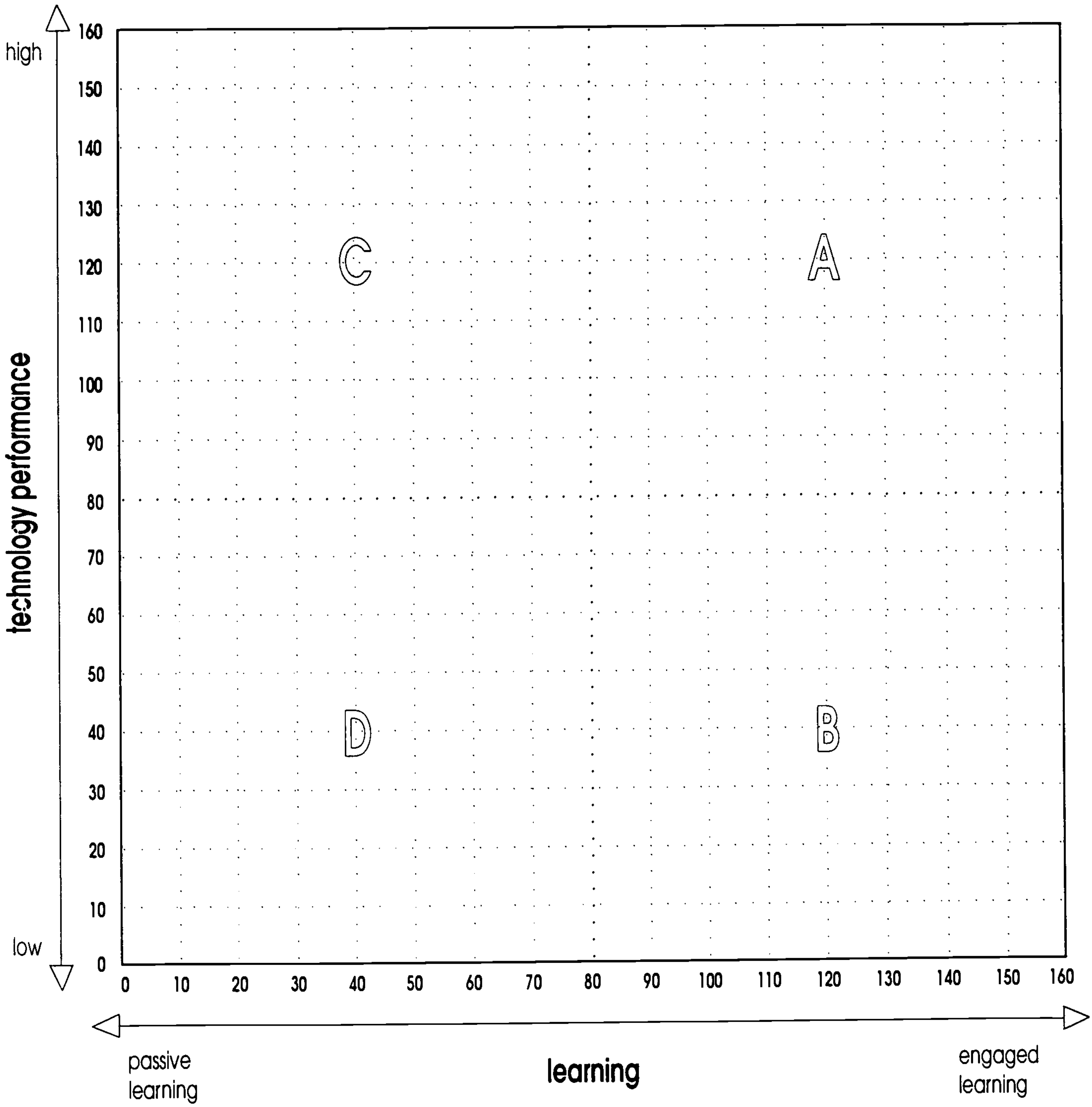
Program A. Using Table III column totals, add the Design and Practice columns for Program A in chart 1 and enter the total in the Grand Totals box. Then add the Design and Practice columns for program A in chart 2, again entering the total in the Grand Totals box.

With grand totals for engaged learning and technology performance of Program A, you are ready to plot each total on the graph. Plot the grand total for engaged learning on the horizontal learning axis by drawing a vertical line. Plot the total for technology performance on the vertical technology performance axis by drawing a horizontal line. Mark the intersection of the two lines with an "A" to indicate the overall effectiveness of program A.

Program B. Plot Program B in the same way as Program A — adding each column and plotting engaged learning with a vertical line on the horizontal axis and plotting technology performance with a horizontal line on the vertical axis. Mark the intersection of the two lines with a "B" to indicate the overall learning effectiveness of Program B.

Comparing points A and B will indicate which technology will be most effective in your classroom.

Graph 2: Comparing Technology Programs



We encourage readers to remove this section and duplicate it for use in group planning sessions.

The Technology Effectiveness Framework

Now that we have meaningful and appropriate indicators for engaged learning and for high technology performance, we can use them to measure the extent to which individual technologies and technology-enhanced programs are effective — that is, the extent to which they support engaged learning.

This framework posits that the intersection of two continua — learning and technology performance — defines technology effectiveness

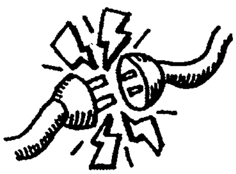
To this end, we have developed the *technology effectiveness framework.* This framework posits that the intersection of two continua — learning and technology performance — defines the effectiveness of a particular technology in student learning. The framework's horizontal axis is *learning*, which progresses from passive at the low end of the continuum to engaged and sustained at the high end. The vertical axis is *technology performance*, which progresses from low to high. This is illustrated in Table 3.

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

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

How to use the framework

The framework gives educators, researchers, and policymakers a way to evaluate technology and technology-enhanced programs and curricula against the *learning goals* they have for their student. Before doing so, however, these decision makers need to *define* their learning goals. That's where the trajectories for change come in.



Directions for Change

The framework encompasses four positive (desirable) directions for change:

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

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

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

Type IV trajectory: 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 engaged learning, there is little reason to pay the higher cost for greater functionality.

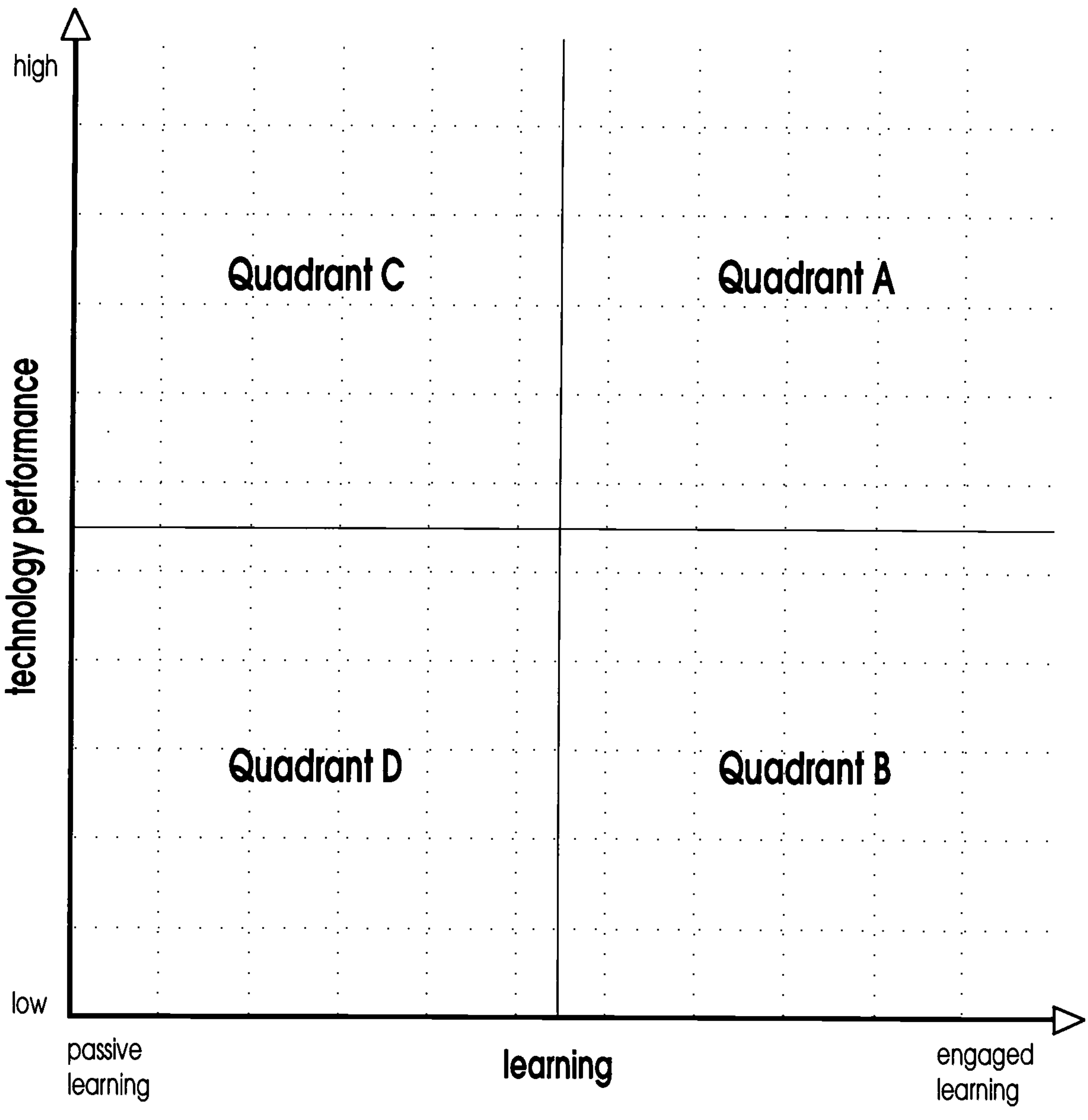
Once the school or school district establishes its curricular goals, the trajectories can guide it in determining what technologies can move learners toward these goals.

Our framework provides a powerful matrix for analyzing particular technologies and programs in broad terms.

This framework provides a powerful matrix for analyzing particular technologies and programs in broad terms. Decision makers can use it as they select and work toward specific curricular goals to promote engaged learning. Researchers, curriculum developers, and staff developers can use the framework to design technologies and technology-enhanced programs. And schools can use the framework to evaluate technology and its costs. In doing so, the critical questions are:

- What are the learning goals (i.e., the vision of learning) to which technology is applied?
- How are these learning goals moving the school toward reform?

Table 3: The Learning and Technology Framework



- How will a technology-enhanced curriculum support instruction that addresses those learning goals?

- 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?

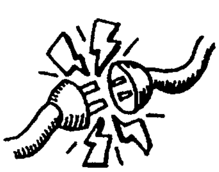
- Can the school extend or adapt less functional technologies so that they are more functional in supporting a global community of learners in sustained learning that is challenging and authentic?

- Are there funding strategies or partnerships that can reduce the cost?

- How can a school continuously plan to use technology to reach for more powerful learning goals and reform?

Applying the framework

This section analyzes four types of technologies — e-mail, computer-driven approaches and software, integrated learning systems, and distance learning approaches — to show decision makers how they can use our framework. The discussion centers on the learning and technology performance indicators presented in Tables 1 and 2 and the broad categories and trajectories presented in Table 3.



Getting Down to the Nitty Gritty

This section gives a general description of how to use the framework. For readers who would like to use the framework to measure engaged learning and technology effectiveness in their own schools and districts, full instructions appear in the yellow section of this document. Part 1 of this insert provides instructions for establishing a vision of learning based on the effective use of technology. Part 2 provides complete instructions for using the framework to compare technology programs.

Our purpose here is not to analyze the technologies by working systematically through each indicator. Rather, we aim to develop a general idea of how the framework would describe each type of technology from the perspective of engaged learning and high technology performance. Specifically, we:

- categorize how each technology is typically used in schools;
- highlight some exemplary approaches/programs in each technology; and
- consider how the design and/or school uses of each technology could be configured to move more toward engaged learning and high performance (quadrant A in Table 3).

1. **E-Mail.** By itself, e-mail is an inherently low-performance technology because it has only one function — to communicate. Issues of access, operability, resource distribution, and many of the design for learning indicators do not apply. However, e-mail gives schools access to rich learning experiences — such as communicating with a tutor or mentor — and collaborative work.

To some extent, e-mail does let students interact and explore, but some of these interactions and explorations are more powerful than others. For example, although using e-mail to write to pen pals in another state may provide some interesting — and perhaps even some powerful — learning experiences, these are episodic and unplanned events. For more sustained challenges, students could use the same e-mail system to explore deeply complex cultural and linguistic issues or solve problems with distant peers over a period of time; teachers could communicate with practicing professionals and community members; and both students and teachers could conduct collaborative projects.

2. **Computer-Driven Approaches and Educational Software.** Obviously, the technology performance level of computer-driven approaches and educational software varies according to the individual approach and the learning context or purpose to which it is applied. Computer-based instruction (CBI) used for drill and practice on traditional objectives does not engage learners and has low technology performance.

On the other hand, computer-based technologies derived from artificial intelligence and research in cognitive science promote engaged learning. Such systems help learners think through complex, authentic problems; take charge of their own learning; and develop products for teaching or use in the real world. These systems integrate 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 and remediate specific learning problems;
- adjust or adapt the level and sequence of problems based on student performances and suggest directions for new learning; and
- simulate the use of emerging technologies and decision making to address complex real-world problems and issues, thereby providing learning by doing and guided participation.

Increasingly, computers will "read" and "think" like humans. When this happens, they will be able to track and respond to complex lines of inquiry. Even now, computers and integrated media can — and frequently do — prompt learners in pursuing more difficult tasks. This means that, when evaluating computer-based technologies, it is important to consider the intelligence or "thinking" the computer can do — as well as its purpose or use in achieving a given instructional or learning goal.

3. Integrated Learning Systems (ILSs). Integrated learning systems provide information from a central source using LANs for communication within and between schools. Many schools believe that because they have a high technology performance ILS, they provide engaged learning and access to rich resources. ILSs provide in-service training on the program's system and content, easy-to-use and time-saving management tools, and good support for technology. Some programs are interdisciplinary and include multimedia encyclopedias. The fallacy in this thinking, however, lies in the fact that ILSs generally support traditional tasks and assessments, traditional student and teacher roles, and traditional instructional approaches targeted to basic skills. ILSs' centralized resource configuration also limits their usefulness.

Many schools believe that because they have a high technology performance ILS, they are providing engaged learning and access to rich resources.

LANs, especially with regard to ILS, so far have not produced significant school change. One reason may be that while most schools have the modems that would link them to other education and information sources, their network technology is primarily for downloading instructional materials from a central repository to isolated classrooms.

Remedying this limitation requires connecting the LANs to WANs and other distributed systems, including the Internet, that provide external resources and opportunities for active learning and communication.

ILSs could support engaged learning in other ways too. For one thing, some ILSs enable schools to access third-party software. Also, some ILSs have multimedia production capabilities that allow teachers to create their own curricular models and allow students to produce an array of documents and other products. A few ILS companies are developing networks outside the system, instructional designs that focus on authentic tasks, and ongoing professional development. One ILS boasts of satellites and video cameras that allow for two-way video communications among networked schools. All of these options increase the usefulness of ILSs.

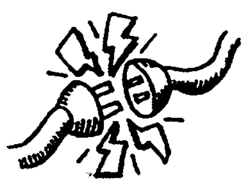
4. Distance Education Technologies. Distance learning technologies traditionally employ one-way video with two-way audio, two-way audio/video, or two-way audio and/or audio graphics (a combination of audio conferencing with graphic support such as an electronic blackboard, still video, or computer-generated visual material) to present instruction or information not otherwise available to remote locations. The major distance education providers include the Public Broadcasting System; TY-IN Network in Webster, Texas; the Ohio-based Satellite Educational Resources Consortium; the Arts and Sciences Telecommunications Service of Oklahoma State University; and many of the Star Schools projects. Additionally, several states offer distance education courses and resources.

Distance education instruction is equivalent to instruction in regular classrooms.

Studies show that regardless of the quality of the production or the specific technology used, students learn equally well with each distance education technology; they also learn as well as students who obtain the information "face-to-face." Thus, distance education instruction is equivalent to instruction in regular classrooms, with the added bonus that it can provide such instruction to students who would have no, or very limited, instruction without it.

But this is not enough. The next generation of distance education technologies must promote engaged learning. And, in fact, both distance learning providers and models are evolving to this end. Already, more distance learning programs are using interactive and networked designs that use computers, telephones, videos, facsimiles, audiographics, and other technologies.

Additionally, the Internet is fast becoming the nation's major vehicle for distance education at all levels. The Internet makes available resources and information previously accessible only by satellite, video, or in person. World Wide Web (WWW) browsers, such as *Mosaic* or *Netscape*, transport video and voice images and support distance education. The Internet's access to digital libraries that offer collections of art, historical papers, and other unique or rare items on demand are also powerful tools for distance education.



Distance Education Quests: JASON

The JASON series of satellite-based projects takes students and teachers on electronic expeditions with world-renowned oceanographer and archeologist, Robert Ballard. Ballard takes cameras into oceans, caves, rain forests, coral reefs, and the Mayan ruins of Belize. Students and teachers can communicate directly with him and other project participants by computer and video teleconferences. The project provides — among other things — bulletin boards, software to downlink text files and data from project sites, instructional materials, and challenging problems.

Policy Issues in Using Technology For Engaged Learning

In order for technology to effectively promote engaged learning for all students, certain elements inside and outside the classroom must be in place. This section identifies several sets of policy issues that affect a school's ability to use technology for engaged learning experiences. While policymakers at local, state, and national levels are addressing many of these issues, their efforts are largely uncoordinated. But even more alarming is that in many cases, no group of policymakers is addressing the issues deliberately and systemically.

Equity

Technology is a tool that gives everyone an equal chance to learn. Given its significance in national and local policy, the first issue concerns equity, or the goal of universal participation.

Policymakers at a national level have made a commitment to building a national infrastructure and achieving universal participation. But that's not enough. State policymakers must make this commitment as well, since the bulk of technology funding is expected to come from states. Finally, local policymakers must guide the implementation of technology.

Universal participation, as a policy goal, means that all students in all schools have access to and are active on the information highway.

Universal participation, as a policy goal, means that all students in all schools have access to and are active on the information highway in ways that support engaged learning. Inequities will be reduced because everyone will have equal access and equal opportunity to learn. However, the danger is that many poor schools will be precluded from these learning activities because:

- schools don't have the funds to buy the needed technology;
- curricula and assessment programs focus on low-level skills even when technology is applied;
- teachers don't have the support they need to develop instructional strategies to use with the information they can access through the technology; and

- bureaucracies keep communication and development from moving beyond the walls of the school into business and community sectors.

Equity and the High-Risk School

If we believe that all students can learn, we must overcome barriers to all students using technology. For schools with high populations at risk, policymakers must:

- provide opportunities for administrators, teachers, and students to become informed about and experience the best technologies and technology-enhanced programs;
- establish curricula and assessment that reflect engaged learning to the highest degree for students at risk;
- give teachers permission and time to explore and experiment with new learning and instructional methods; and
- provide ongoing professional development to develop new learner outcomes, curricula, and assessment that use the best technologies and programs.

Standards

The second policy issue involves making sure that there are high standards for all children and that students have opportunities to complete challenging tasks using technology.

Major barriers exist, however, to implementing such policies at the local level, including:

- local assessments that focus on low-level and conventional objectives;
- technology initiatives that are divorced from curriculum, instruction, and assessment; and
- tracking systems that separate students and technology into low and high-level applications.

Policies need to integrate curriculum, instruction, assessment, and technology. These policies will ensure that, in practice, a school's curriculum, instruction, assessment, and technology seamlessly support engaged learning.

We also need national standards for what constitutes high-performance technologies that promote learning.

Finance

School funding formulae that depend on residential property taxes have long impeded school reform in the cities. If education is to change, the tax and funding structures of schooling must be part of that change. This issue raises questions about funding technology for specific settings (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 need to consider designing and financing state and multistate technology infrastructures for these special circumstances.

Also, today's educational system centralizes the purchase and distribution of textbooks, equipment, supplies, and services. Such a top-down approach permits cost-effective, high-volume purchasing. But, it is also terribly out of step with today's needs. The new technology-driven organization must address this issue.

Technology legislation in progress may alleviate some of the funding crisis and go some distance toward helping poor schools provide 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."

Coordination

Familiarizing students with workplace technologies — by ensuring coordination of technology choices and uses from K-12 to postsecondary education and to work — can greatly strengthen the transition from school to work. Employability is an important concern for all students, and experience with a technology that has high transferability to the community and workplace is crucial.

By extending our efforts, we could provide students with many basic workplace technologies such as word processing, multimedia formats for presentations, and spreadsheets. Vital also is how we can expose students to and give them practice with expensive, context-specific technologies.

The present strategy for purchasing and using technology in K-12, postsecondary, and school-to-work programs is not coordinated. Coordination involves many different policy players and many different configurations of technology and telecommunications. Private and public sector planning could facilitate shared financing and improve technology access and use in school-to-work programs.

Promoting Workplace Technologies for Students

Some school-to-work transition initiatives promote students' use of workplace technologies. For example, museum exhibits and specially designed workstations in schools give students sustained learning experiences with high-performance technologies that promote engaged learning.

Two emerging models of teaching and learning address the focus on school-to-work transition: cognitive apprenticeships and knowledge-building communities. These models emerge from research on learning, but have a natural affinity for school-to-work issues because both seek to engage learners and communities in the social relationships so critical in the workplace.

Commitment

Emerging consensus is that it is not enough to provide the technology and connections so that all educators *can* participate in making decisions about learning and technology; rather, it is vital to provide ongoing professional development so that all educators *will* participate. Commitment to ongoing professional development prepares educators to implement the instructional and curricular strategies implied in our framework. This commitment involves time, financing, staffing, and powerful models based on recent research on learning, professional development, and technology emerging from cognitive science and related fields.

Role of the parents

A final issue for policymakers is the role of parents in school-based technology programs. While several technology and technology-enhanced programs do involve parents and local community members, most do not. Consequently, many parents do not understand the educational shift toward technology use. They do not understand its significance in their children's schooling and on their children's later capability in the workplace. Additionally, many people fear and misunderstand technology itself. The solution is to bring parents into partnerships with the school and the teachers, to explain programmatic goals and to draw on parental resources.

Putting Policy Into Place

As decision makers begin to implement technology and technology-enhanced programs as a way to promote engaged learning, the face of education will change. There will be new educational services and service providers, new capabilities and organizations in schools, and new levels of student achievement. These changes will create needs for new methods of evaluation, needs for information and data, and — above all else — a pressing need for a national infrastructure to support these changes and to ensure that they get implemented equitably.

Regionally based solutions and innovations are critical to the development of this national infrastructure. To this end, we propose several mechanisms for distributing technology information and educational resources — both on-line and on-site — across multistate regions.

New educational service providers

Technology will profoundly change who delivers educational services and content to schools. Federal agencies; regional, state, and local initiatives; the educational R&D community; and electronic publishers will increasingly replace conventional textbook publishers as the next generation of content providers for schools.

1. **Federal Agencies.** Recent policies have permitted federal agencies to release huge repositories of free information and educational resources to schools through the Internet. These resources include data from the National Aeronautics and Space Administration (NASA), the U.S. Weather Service, federal energy laboratories, the Departments of Labor and Commerce, and agencies and offices involved in oceanographic and environmental matters. The providers offer varied activities. NASA, for example, offers a model classroom of the future, massive databases of planetary images, and five regional teacher centers, among other resources. And, in addition to releasing various data sets on the planets, weather, and energy, several of the energy laboratories are developing software to deliver three-dimensional images and virtual reality to schools over the Internet.

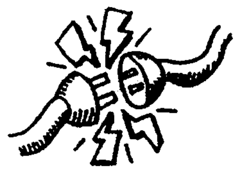
2. Regional, State, and Local Initiatives. Various regional, state, and local initiatives are providing content and services to schools, again, through the Internet. Among them are the regional educational laboratories, museums, libraries, zoos, and various health agencies. Indeed, there is a high-level movement to encourage informal consortia among these groups. 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. Both institutions are forming consortia to develop ongoing projects and outreach to schools using the Internet. The Chicago Library System, which includes all of Chicago's library groups, is working with the library at the University of Illinois to develop a two-way video desktop conferencing capability.

3. Educational R&D Community. A third category of providers is the R&D community of universities and private nonprofit agencies devoted to improving education. Several formal and informal consortia — made up of researchers from academia, nonprofit organizations, and businesses — already exist and 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 the information highway system that will carry the content and services they have designed.

4. Electronic Publishers. A fourth set of providers consists of electronic publishers, broadcasters, distance learning providers, the video and film industry, telecommunications and computer companies, and the business community at large (both the industry "giants" and the small businesses) that will provide content, networking, and educational services. These providers will have increasing interest in and control over the educational materials available to schools.

New information and services

Electronic networks will enable schools to receive up-to-the-minute data from every sector of society around the globe. Schools will become part of a worldwide network with research agencies and practicing professionals to build knowledge communities. Many of the new data sets they access will be in picture and video formats. Therefore, video networking, integration, and management in schools will become critical. A major part of this infrastructure is the development of digital libraries and museum learning environments to help students and teachers access, browse, manipulate, and interact with image and video data.



New Formats, Lower Costs?

The Internet and emerging video and imaging technologies could change not only how schools get information and services, but also the very economics of school service delivery itself. The content and services available through the Internet and other telecommunications resources — many of which are free or of nominal cost — could ultimately replace most of the textbooks and other costly instructional materials, software, and programs that currently bite hard into most school budgets. If schools were to draw largely upon these free resources and services, they could spend far more of their budgets on staffing, curriculum development, technology growth, staff development, and school restructuring.

New capabilities and organization in schools

The widespread application of technology to promote engaged learning will yield several exciting changes in the ways schools organize curricula, define teacher and student roles, and structure themselves. These changes, in turn, will significantly affect student achievement.

- **Greatly expanded information exchange capabilities.** New technologies and tools such as World Wide Web, e-mail, distribution lists, and group mail reflectors will give schools greater access to text, audio, and video, as well as to search tools and bulletin boards for exchanging local and global resources.

- **Curriculum organized as projects involving sustained and complex co-investigations.** Students will participate in projects without regard to geographic and political boundaries, and interact with practicing scientists and other professionals. Such projects offer students the opportunity to make real contributions to science, literature, and other areas within local and global communities.

- **Changes in student and teacher roles.** Teachers and students will increasingly become 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 will become resource managers or brokers.

- **Accelerated curriculum and school restructuring to promote learning.** Many schools are implementing interdisciplinary curricula and themes that revolve around the use of technologies — especially those involved in accessing the Internet. The primary source of this energy is the extraordinary motivation that many users derive from working on authentic tasks and collaborating with others in a learning community. Projects that ask students to perform challenging and authentic tasks align curriculum, instruction, and assessment into one seamless experience.

- **Changes in student achievement.** Several technology-enhanced curricula show that they can improve student achievement on standardized measures. Pogrow's HOTS Program (Higher Order Thinking Skills) and the Jasper Woodbury Series, developed by the Cognition and Technology Group, for example, are perhaps the most well-documented; both are effective with students at risk. Numerous other programs appear promising based on data, documentation, surveys, and classroom observations. These studies show that students improved their understanding of concepts, engaged in more active learning, preferred more difficult questions and challenging tasks, demonstrated more student leadership, and engaged in more authentic tasks that produced real products or services for real audiences.

New ways create needs

These new ways of providing instruction will create several significant needs. Some of these are highlighted below.

1. **We will need new ways to evaluate effectiveness.** Already, there is growing skepticism about using standardized tests and traditional study designs (e.g., pilot studies with control groups) to measure the effectiveness of technology as a learning tool. In this regard, national testbeds are an important new concept. The purpose of these testbeds is to study technologies and programs that move toward universal access and participation in mathematics and science. A testbed combines 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.

Testbeds use an array of qualitative and quantitative measures, including surveys of teachers and students, in-depth interviews, analyses of recorded communications and products, and classroom observations. The testbed analysis looks at changes in school organization, policy, programs, and practices.

2. Need for tools for knowledge and community building. We will need tools to evaluate technology and learning. These tools should make clear what a school's current realities are and compare them to its future vision. They should also enable us to compare one particular technology-enhanced program or curricula to another. Finally, schools will need new tools to help identify preferable technology features and agencies that can support them.

These tools should make clear what a school's current realities are and compare this to its future vision.

On a related note, there is also a need to document: (1) what tools already exist for teaching and administrative functions such as curriculum development, records management, and professional development; (2) what tools are available to help students access powerful databases, make decisions, solve problems, and communicate; and (3) what tools students need to carry out these functions in learning.

3. We will need a national database. New technologies and studies of technology are emerging rapidly, constantly extending the outer limits of what is possible and within reach. Already, the print medium is hard-pressed to keep up with and report on these developments. What we need, therefore, is a national database that will provide:

- high-level, synthesized research in easy-to-read formats for policymakers at all levels; and
- in-depth, richly detailed information for researchers and educators.

Using this national database, policymakers, researchers, and educators alike could access information on such important questions as:

- How do successful schools and library systems "grow" technology expertise?
- What strategies do poor schools use to obtain funds for powerful technologies?
- What methods overcome barriers to establishing technology-enhanced schools?

- How can the marketplace be induced to develop interactive technologies that build on existing video/television equipment in schools and homes?

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

The national database could also allow schools and districts to examine and compare the various design features of new technology programs, and to analyze the advantages and disadvantages of different implementation strategies.

We will need comprehensive human/technology infrastructures

Just as important as a technology infrastructure is the human infrastructure that must accompany it. The development of this human infrastructure is crucial to increasing opportunities to learn for millions of students, teachers, and administrators and to provide ongoing support. It would give educators the strength they need to maintain a place at the table when decisions about technology are being made. The challenge is to think in terms larger than a school, district, or state, thereby sharing the cost of the human and technology infrastructure.

One possibility is to create a set of regionally-based agencies to coordinate the evolution and natural emergence of trends — or to drive these trends as their primary agenda. Such agencies would have to be well-equipped, well-planned, and well-coordinated, not only to deliver restructuring services to schools but also to deal with the many equity issues in technology and learning.

Some brief sketches of such innovative regional agencies follow:

1. **Regional Info-Port.** Regional information distribution and coordination centers would involve a diversity of players using the Internet and other free telecommunications sources. Each port would:

- transport low-cost or free resources for schools;

- support school collaborations using video, audio, and text technologies, and focus on bringing the poorest schools in urban and rural contexts into collaborations;

- link the schools to practicing scientists and community members across the globe;

- work with schools to develop technology plans, and work with higher education and other agencies to develop professional development programs for technology specialists and librarians; and

- provide ongoing support for school restructuring to promote engaged learning — again, especially for schools for the poor and minorities.

Regional info-ports would create a distributed technology infrastructure that could serve thousands of users simultaneously. The human infrastructure needed to develop this technology and share its costs could include a configuration of computer companies, the Departments of Labor and Energy, telecommunications agencies, power companies, local private sector groups, the military, and local civic organizations, all in collaboration with educational agencies.

2. Regional School Service Cooperative. In addition to an information port, there would be a need for service outreach. A service cooperative providing such outreach could:

- help schools *access and use the resources* available from the Internet and the port so as to address national reform initiatives and promote collaboration;

- promote *equitable access* to and use of technology-enhanced learning opportunities;

- develop a new generation of *regionally-based and supported learning communities* that define the learning place as wherever the learner can access technologically;

- develop *evaluation designs* for use with technology;

- study and develop *new policies* to cover technology-supported learning contexts and situations;

- provide *training and support services* to use technology; and

- work with schools to generate *learning experiences for professional development.*

3. Regional Service Universities. A regional service university might be a physical entity with its own human, fiscal, and political infrastructure, but be set up by consortia of universities in a region. Conversely, such a university could be "virtual," made up of a set of courses operating as an "invisible college" without dedicated human, fiscal, and political infrastructures. In either case, a regional service university 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 or new human needs in schools such as for digital librarians and school technology specialists.

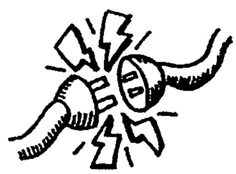
4. Educational Enterprise Communities. Increasingly, we are looking beyond individual schools to entire communities as agents of change. We envision educational enterprise communities spread out over a multistate area, with schools and communities working together to identify needs, design and create learning environments that address those needs, and develop policies through rapid prototyping.

- Schools, communities, and researchers working collaboratively to develop local and electronic communities 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 learning opportunities.

- 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 instructional units; (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 satellite 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, multimedia 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.



Regional Innovations: The Bottom Line

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 achievement, 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 learning to cooperate and build consensus to solve educational problems together. And, they are about building enterprise webs that serve new economic and political bases for education.

Recommendations for Policymakers and Educators

1. **Schools should not support a technology design that does not empower learning.** This does *not* mean that schools should abandon technologies that support low-level learning goals. These technologies still have value, 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 is *adapting* these technologies to support engaged learning.

2. **Schools should move toward distributed networks, as opposed to central source providers, in order to build communities of learners that include students and teachers as contributors.** This does not mean that schools should abandon all projects or services involving central source providers or unnetworked software. There are some stellar projects that use central source providers as their base. These provide a high-quality product and service for schools that is motivating teachers and students and promoting engaged learning. The same is true for many tools that may — or may not — feature open architecture and high technology, but which provide powerful opportunities for teachers to solve problems, develop curricula, and so on. However, the key here is *adapting* the technology to be more interactive and focused on engaged learning using networking and the Internet.

3. **Schools must use technology — regardless of the specific one selected — to create powerful learning designs.** Such designs 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.

4. **Many schools can begin their technology-supported initiatives by investing in low-end technologies with high learning options.** Schools need to become collaborators with research-based service providers. This would let teachers experience what it means to use technology effectively for communication and learning. Such projects should allow teachers to experiment with different models of instruction and different approaches to technology. During this experimentation phase, schools can evaluate cost effectiveness in terms of their learning goals.

5. Schools must, from the outset, plan on connecting their technologies. As a school grows in its experience and expertise, it can develop more powerful models of learning using more complex technologies — all the time moving toward high-technology, high-learning options. Also, schools in the high-technology, low-learning quadrant (see Table 3) should consider new options. They might move from closed-system ILSs and distance learning technologies that are providing direct instruction toward more interactive technologies, open architecture, connectivity to distributed resources, and more engaged learning experiences through their existing technologies.

6. Schools cannot invest in technologies alone. They must also invest in ongoing professional development, training, and support services. Research-based agencies that focus on learning and collaboration often support successful technology programs. As technology vendors seek long-term relationships with schools, they too will need to develop expertise in learning and will have to be able to provide professional development using their specific technologies and programs.

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