Apple Classrooms of Tomorrow—Today

Learning in the 21st Century

Background Information
April 2008

Contents

What Is ACOT²?

Apple Classrooms of Tomorrow—Today (ACOT²) is a collaborative effort with the education community to identify the essential design principles for the 21st century high school by focusing on the relationships that matter most: those between students, teachers, and curriculum.

ACOT² follows in the tradition of Apple Classrooms of Tomorrow (ACOT), a research and development collaboration among public schools, universities, and research agencies that Apple initiated in 1985 and sustained through 1995 with outstanding results. Its goal was to study how the routine use of technology by teachers and students might change teaching and learning. ACOT identified effective models for teaching and learning with technology, developing the professional lives of teachers, and diffusing innovation.

The goal of ACOT² is more targeted: to help high schools get closer to creating the kind of learning environment this generation of students needs, wants, and expects so they will stay in school. To that end, ACOT² is pursuing a strategy in three phases:

- In the first phase, ACOT² developed the essential design principles of the 21st century high school, and then clearly and simply articulated them so any high school can act on them immediately.
- In the second phase, ACOT² brought the essential design principles to life through online resources, including "clickable" data, research, expert commentaries, tools, and rich media capturing students' and educators' voices. The voices offer especially compelling testimony for why and how these design principles should be implemented in our nation's high schools today.
- In the third phase, ACOT² will take these design principles and apply them to a bold project: 200 Days for a Lifetime of Success, a freshman year high school curriculum specifically designed to prepare students for success in life and work in the 21st century.

This report and the ACOT² website (http://www.acot2.com) present the rationale for urgent action in our nation's high schools and offer a detailed presentation of the ACOT² design principles.

Executive Summary

Apple Classrooms of Tomorrow—Today (ACOT^2) is a collaborative effort with the education community to identify the essential design principles for the 21st century high school by focusing on the relationships that matter most: those between students, teachers, and curriculum. The factors driving ACOT^2 are these:

- America is caught in the grip of a crisis in education that threatens the ability of an entire generation of young Americans to achieve success in life and work. The crisis also threatens America's ability to remain competitive on the global stage.
- Especially vulnerable are our high school students. Research on high school dropout rates and causes highlights the severity of the situation. Nearly one in three high school students in America this year will not graduate.
- Current education reform strategies are inadequate or failing.

ACOT^2 assumes as its starting point that time-honored yet outmoded approaches to education and education reform must be replaced with new and creative ways of thinking about designing learning environments for this generation of students.

The ACOT^2 strategy is to offer a simple, clean approach that focuses on the essential design principles of the 21st century high school—rather than a more prescriptive school reform model. While the design principles themselves are not new, what is new is that the complexity that characterizes most education reform models has been cleared away, enabling immediate action and results.

Applying this philosophy, ACOT^2 has identified six design principles for the 21st century high school:

- **Understanding of 21st Century Skills and Outcomes.** Establishes as a baseline that educators, students, and parents must be well versed in the 21st century skills that students need to acquire to be successful. Teachers should be able to make relevant and useful choices about when and how to teach them, and whether or not students are making progress toward their personal demonstration of accomplishment. Rethinking what we teach must come before we can rethink how we teach.
- **Relevant and Applied Curriculum.** Offers an innovative vision of what the learning environment should be by applying what we know about how people learn and adapting the best pedagogy to meet the needs of this generation of learners. Students should be engaged in relevant and contextual problem-based and project-based learning designed to apply 21st century skills and that is provided using a multi-disciplinary approach. Curriculum should apply to students' current and future lives and leverage the power of Web 2.0 and other ubiquitous technologies.
- **Informative Assessment.** Identifies the types and systems of assessments schools need to develop to fully capture the varied dimensions of 21st century learning as well as the independent role students need to take on in monitoring and adjusting their own learning. Assessments used in the classroom should increase relevant feedback to students, teachers, parents, and decision-makers and should be designed to continuously improve student learning and inform the learning environment.

- **A Culture of Innovation and Creativity.** Acknowledges the fuel that drives today's global economy and, in turn, its importance in both student learning and the school environment. As a result, schools should create a culture that supports and reinforces innovation for student learning and leverages the creativity and ingenuity of every adult and student in their environment to solve their unique problems. Additionally, the teaching and learning environment should generate the continuous development of those skills.
- **Social and Emotional Connections with Students.** Gives appropriate recognition to the personal, professional, and familial relationships that determine the health, growth, and cognitive development of a child within the family, school, and community. Specifically, each student should have a clear and purposeful connection to the social environment in school, with at least one adult who is purposefully in tune with the student's learning preferences, learning interests, and social connections.
- **Ubiquitous Access to Technology.** Underscores the essential role technology plays in 21st century life and work and, consequently, the role that it must play in learning. Students and educators need 24 by 7 access to information, resources, and technologies that engage and empower them to do background research, information and resource gathering, and data analysis, to publish with multiple media types to wide and varied audiences, to communicate with peers and experts, and to gain experience and expertise in collaborative work.

  This report and the ACOT^2 website (http://www.acot2.com) explore each of these six design principles in detail, including the current research that supports their inclusion in this approach.

Part I
The Challenge for American Education

America is caught in the grip of a crisis in education that threatens the ability of an entire generation of young Americans to achieve success in life and work. The crisis also threatens America's ability to remain competitive on the global stage.

The need for action is urgent, and especially vulnerable are our high school students. Research on high school dropout rates and causes highlights the severity of the situation: Nearly one in three high school students in America this year will not graduate.[1]

Every 29 seconds, another high school student in America gives up on school, resulting in more than 1 million high school dropouts every year. Nearly one-third of all public high school students—and nearly one-half of all African American, Hispanic, and Native American students—fail to graduate with their class. In nearly 2000 high schools in the United States, the typical freshman class loses 40 percent of its students by their senior year.[2]

The long-term impact of high school dropout rates on our society is catastrophic. Dropouts are more likely than high school graduates to be unemployed, in poor health, living in poverty, on public assistance, and to be single parents with children who also drop out of high school. They are eight times more likely than high school graduates to be in jail or prison. They are four times less likely to volunteer than college graduates, twice less likely to vote or participate in community projects, and they represent only three percent of actively engaged citizens in the United States today.[3]

Most students report that dropping out of high school is a gradual process of disengagement that results in the lack of social or emotional connection to school. The good news is that the disengagement process can be reversed with more relevant, challenging coursework and individualized support from schools, educators, parents, and community.

Preparing Students for Life and Work in a Changing World

Young Americans coming of age in this century—the 70 million people born between 1982 and 2000—live in a world that is dramatically more complex than it was just a few years ago. In a remarkably short period of time, the world and its people, economies, and cultures have become inextricably connected, driven largely by the Internet, innovations in mobile computers and devices, and low-cost telecommunications technology.

This global interdependence has profound implications for all aspects of American society—from how we think and work to how we play and learn.

In business, for example, 9 to 5 has been replaced by 24 by 7, as technology keeps us "always on" and our markets and workforces extend across every time zone. And the focus of business is changing to match the largest growth opportunities—those abroad. International commerce now accounts for a quarter of the American economy and is fueling a third of U.S. economic growth.

The business case for global markets is compelling, and to compete abroad successfully, American companies need a workforce equipped to translate American business models and offerings to international marketplaces.

Moreover, many of the challenges facing us—geopolitical tensions, climate change, and disease pandemics—are global in nature and scale, and thus demand cross-border perspectives and solutions.

In such a world, tangible skills such as language proficiency are obviously critical to success. But language skills are just part of the equation. To be productive global citizens, Americans need other skills that are less tangible, including greater sensitivity to cultural differences, openness to new and different ideas, and the ability to adapt to change.

The massive amount of information and opinion available to us offline and online can help us meet these challenges, but awash in this sea of information, each of us needs to be able to sort fact from fiction and evaluate and interpret conflicting ideas. We also need to know how to work collaboratively and creatively in person, by telephone, and online to make decisions and take action.

Educating young people to be successful in this changing world is no small task, but the consequences of failing to do so are enormous. Current data show that high school graduates in jobs requiring the highest degree of innovative thinking earn more than 50 percent more than those in jobs requiring the least innovation. For college graduates, the difference is 135 percent.[4]

A parallel trend shows that our current practice of outsourcing jobs to countries such as China and India is making it more difficult for unskilled American workers to earn middle-class incomes.[5]

These trends, combined with high school dropout rates, make it clear that as a nation, we must rethink what we are now doing to improve K–12 education in America. Increasingly, policy makers and education leaders are doing this.

For example, the No Child Left Behind Act of 2001 requires schools to demonstrate adequate yearly progress (AYP) toward the goal of all students being able to perform at grade level. This has helped focus attention on some of the problems with K–12 education in America and attempted to provide added resources to schools that are failing. But many education leaders believe that No Child Left Behind's demand that progress be measured solely through standardized tests of students' knowledge of a limited number of core subjects has caused many schools to "teach to the test." While this may produce better test scores, it diminishes schools' incentive to focus on teaching methods that engage students and on teaching skills that prepare students for success in life and work in the 21st century.

Equally important, No Child Left Behind has had no impact on keeping students in school. The national high school dropout rate has remained unchanged for decades.

Rethinking Education in America

With a 30-year history of delivering innovative technology and education solutions, Apple initiated the ACOT^2 project to join with other education leaders committed to improving education in America. ACOT^2 assumes as its starting point that time-honored yet outmoded approaches to education and education reform must be replaced with new and creative ways of thinking about the expected outcomes of our schools and the role of educators.

For example, 20 years ago school was the place where students learned information and skills in core subject areas such as English, language arts, science, and history. Educators were primarily information experts who passed along to their students what they had learned in school.

Today, information is readily available from numerous sources. With a computer, the Internet, and a search engine, much of the information students once spent the entire school year learning can be acquired in a fraction of the time or on an as-needed basis. These technology innovations democratize information, giving students direct access to the building blocks of their future knowledge—organized, indexed, and affordable content, resources, and instruction available 24 by 7. It also shifts the locus of control to the student, enabling them to pursue learning both in school (formal learning) and outside of school (informal learning).

These are profound changes that require schools to become more than information repositories; they must also be places where students can acquire knowledge and skills they can use to solve complex problems for the rest of their lives. These changes affect the role of educators even more dramatically. Educators must become more than information experts; they must also be collaborators in learning—leveraging the power of students, seeking new knowledge alongside students, and modeling positive habits of mind and new ways of thinking and learning.

What and How We Teach Must Change

To make these transitions, schools and educators must be well versed in core subjects, the broad range of interdisciplinary knowledge, skills, and attitudes that education and business leaders call "21st century skills," and in teaching methods that engage and inspire students to learn.

Examples of 21st century skills include global awareness, financial and entrepreneurial literacy, information and media literacy, civic literacy, and health literacy. Students also need to acquire skills such as innovation and creativity, critical thinking and problem-solving, information and media literacy, self-direction, adaptability, and accountability.[6]

In terms of teaching methods, schools must recognize that what engages this generation of learners is very different from what may have engaged previous generations.

Students today have grown up in a world where mobile computers, cell phones with browsers, and other personal digital devices are common tools, and instant messaging, blogs, and wikis are common modes of self-expression.

All together, students spend an average of nearly 6.5 hours a day with media.[7] According to the 2005 Pew Internet & American Life Project, 87 percent of 12- to 17-year-olds—or 21 million young people—are Internet users, an increase of 24 percent from 2000. Three-quarters of today's teens use at least two digital devices daily.[8] Students routinely observe adults in professions and workplaces enabled by the same technologies and tools they use in their own daily lives.

Because of today's digital technology, students live a media rich, connected, and mobile lifestyle, and they are just as often producers of content as they are consumers. Web 2.0 technologies, including social networks and participatory sites such as YouTube, MySpace, Second Life, and World of Warcraft, provide them with engaging opportunities for interaction and informal learning, and create new opportunities to leverage this informal learning by integrating it purposefully into the fabric of formal learning.

Not surprisingly, students today expect to learn in an environment that mirrors their lives and their futures—one that seamlessly integrates today's digital tools, accommodates a mobile lifestyle, and encourages collaboration and teamwork in physical and virtual spaces.

Too often, though, these are not the attributes students find at school. For example, one student described going to school as being like flying on an airplane. He has to turn off all his digital devices, strap himself in, and wait until the end of the flight to resume his digital life.

The disconnect between a student's digital life and school matters because students learn better when they are engaged, and research about what engages them points to technology.[9] Numerous studies have shown that effective integration of technology into teaching and learning can result in higher levels of student achievement.

The link between technology, engagement, and achievement is especially important for our K–12 schools because by government mandate, their mission has evolved from providing an opportunity for young people to learn to making sure they do. When students must learn, motivating them to learn becomes essential.

Learning Optimized for the 21st Century

There is no shortage of opinions about why American education reform initiatives have fallen short of their goals and no shortage of new ideas for future reforms. The intent of ACOT^2 is not, however, to belabor past failures or deconstruct new proposals. Instead, our goal is to help high schools get closer to creating the kind of learning environment this generation of students needs, wants, and expects so they will stay in school. The ACOT^2 strategy is to bring 21st century learning into our nation's high schools.

Twenty-first century learning is at the confluence of three major influences: globalization, which increases global interdependence and competition; technology innovations that enable more engaged teaching and learning and provide 24 by 7 access to content and people; and new research on how people learn.

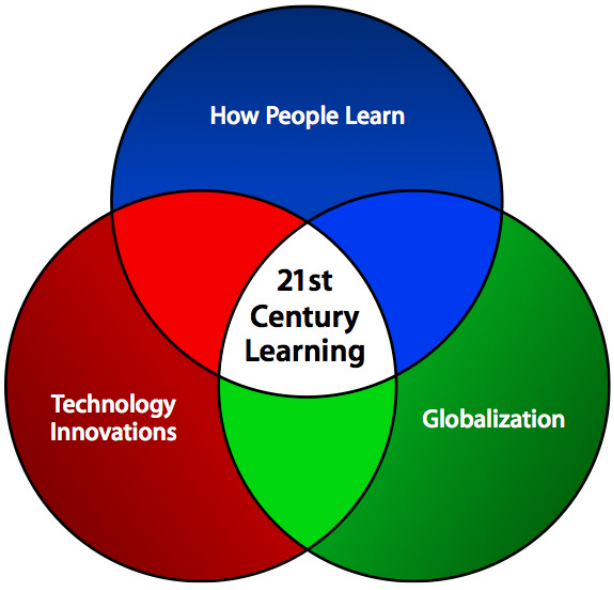

Figure 1: Three major influences on 21st century learning

This report has already discussed the implications of globalization and technology. The importance of research is that it proves what educators have long experienced about how today's students learn best. For example, educators know that students learn best when they learn with understanding, or use what they already know to derive meaning from new information. Awareness and productive use of one's own cognitive processes—metacognition—is also important to learning. However, when combined with new and sophisticated cognitive and neuroscience research on such topics as working memory, cognitive overload, and executive function, these fundamental concepts become breakthrough ideas that can lead to new and better ways of teaching.

There is another cornerstone concept that informs the ACOT^2 approach to 21st century learning and that is the concept of "flow." "Flow" is learning with the volume cranked up, when everything is clicking just right. ACOT^2 believes that the most effective educators create opportunities for students to get into the flow—in the context of subjects and curriculum—by working with them to balance the complexity of the task with their current repertoire of learning strategies.

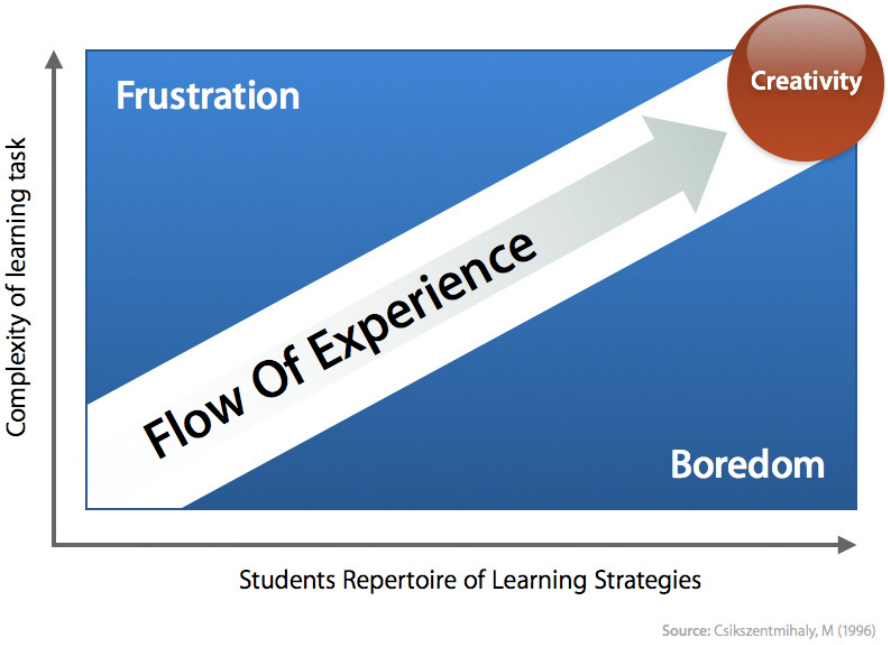

Figure 2: The flow experience in learning

The ACOT^2 Approach: Focus on Essential Design Principles

One of the guiding principles of ACOT^2 is that the need for change is urgent and the time to act is now. This informs the ACOT^2 strategy, which is to offer a simple, clean approach that focuses on the essential design principles for the 21st century high school—rather than a more prescriptive school reform model. While the design principles themselves are not new, what is new is that the complexity that characterizes most education reform models has been stripped away, enabling the principles to produce immediate benefits and results.

Applying this philosophy, ACOT[2] has identified six design principles for the 21st century high school:

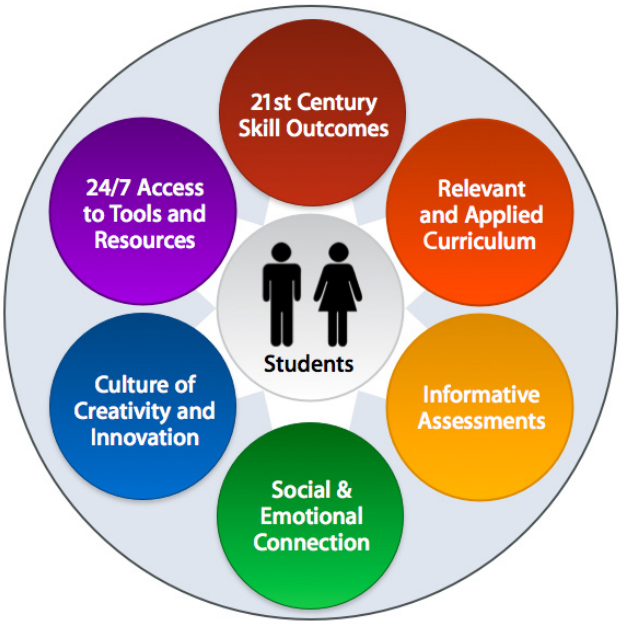

Figure 3: Six Design Principles

- **Understanding of 21st Century Skills and Outcomes.** Establishes as a baseline that educators, students, and parents must be well versed in the 21st century skills that students need to acquire to be successful. Teachers should be able to make relevant and useful choices about when and how to teach them, and whether or not students are making progress toward their personal demonstration of accomplishment. Rethinking what we teach must come before we can rethink how we teach.
- **Relevant and Applied Curriculum.** Offers an innovative vision of what the learning environment should be by applying what we know about how people learn and adapting the best pedagogy to meet the needs of this generation of learners. Students should be engaged in relevant and contextual problem-based and project-based learning designed to apply 21st century skills and that is provided using a multidisciplinary approach. Curriculum should apply to students' current and future lives and leverage the power of Web 2.0 and other ubiquitous technologies.
- **Informative Assessment.** Identifies the types and systems of assessments schools need to develop to fully capture the varied dimensions of 21st century learning as well as the independent role students need to take on in monitoring and adjusting their own learning. Assessments used in the classroom should increase relevant feedback to students, teachers, parents, and decision-makers and should be designed to continuously improve student learning and inform the learning environment.
- **A Culture of Innovation and Creativity.** Acknowledges the fuel that drives today's global economy and, in turn, its importance in both student learning and the school environment. As a result, schools should create a culture that supports and reinforces innovation for student learning and leverages the creativity and ingenuity of every adult and student in their environment to solve their unique problems. Additionally, the teaching and learning environment should generate the continuous development of those skills.

- **Social and Emotional Connections with Students.** Gives appropriate recognition to the personal, professional, and familial relationships that determine the health, growth, and cognitive development of a child within the family, school, and community. Specifically, each student should have a clear and purposeful connection to the social environment in school, with at least one adult who is purposefully in tune with the student's learning preferences, learning interests, and social connections.
- **Ubiquitous Access to Technology.** Underscores the essential role technology plays in 21st century life and work and, consequently, the role that it must play in learning. Students and educators need 24 by 7 access to information, resources, and technologies that engage and empower them to do background research, information and resource gathering, and data analysis, to publish with multiple media types to wide and varied audiences, to communicate with peers and experts, and to gain experience and expertise in collaborative work.

Part II of this report explores each of these six design principles in detail, including the current research that supports their inclusion in this approach.

Part II
ACOT²: The Six Design Principles for the 21st Century High School

Understanding of 21st Century Skills and Outcomes

"We need people who think with the creative side of their brains—people who have played in a band, who have painted, been involved in the community as volunteers. It enhances symbiotic thinking capabilities, not always thinking in the same paradigm, learning how to kick-start a new idea or how to get a job done better, less expensively."[10]

— Annette Byrd, GlaxoSmithKline

Early in this century, leaders and visionaries in the business and education communities joined together to recommend the skills needed to enrich the lives of those living in the 21st century and to make them more successful in their work.

Business leaders were especially outspoken in their call for a workforce well versed in 21st century skills. In a recent survey, business leaders were asked about the skills most needed for readiness for today's business environments.[11] The highest ranked skills for students entering the workforce were not facts and basic skills; they were applied skills that enable workers to use the knowledge and basic skills they have acquired.

For example, the most desirable skills identified were work ethic, collaboration, social responsibility, and critical thinking and problem-solving. Employers also see creativity and innovation as being increasingly important in the future.

Current thinking about these skills is based not only on recommendations from business leaders, but also on research about how people learn. Much of the early research on this topic was carried out by cognitive psychologists during the 1970s and 1980s and focused on how individuals, especially experts, learn and solve problems. Although fruitful, researchers realized that their work did not take into account the rich environment in which individuals worked to solve problems—environments filled with tools and colleagues. This realization has led to the study of learning and solving problems in social environments.

In the 1990s, cognitive psychologists began to study collaboration and the role of social context in learning, while educational researchers began to study collaboration in school settings.[12] These studies underscore the importance of expanding goals that we have for students to include both basic and applied skills and to focus on both individual and collaborative problem-solving.[13]

Through the efforts of the Partnership for 21st Century Skills (P21) and other organizations, specifics regarding these skills have been refined. The Partnership for 21st Century Skills developed a complete framework for articulating these skills, which is being widely adopted by visionary states and school districts. These states and districts are beginning to strategize how these skills might best be supported.

The framework recognizes the centrality of core subject areas in the educational milieu but also emphasizes new themes that must be interwoven across disciplines to increase the relevance for today's learners. In addition, the framework outlines skills

in three areas: Life and Career Skills, Learning and Innovation Skills, and Information, Media, and Technology Skills. Each of these areas is described briefly here, but much more information can be found on the P21 website.[14]

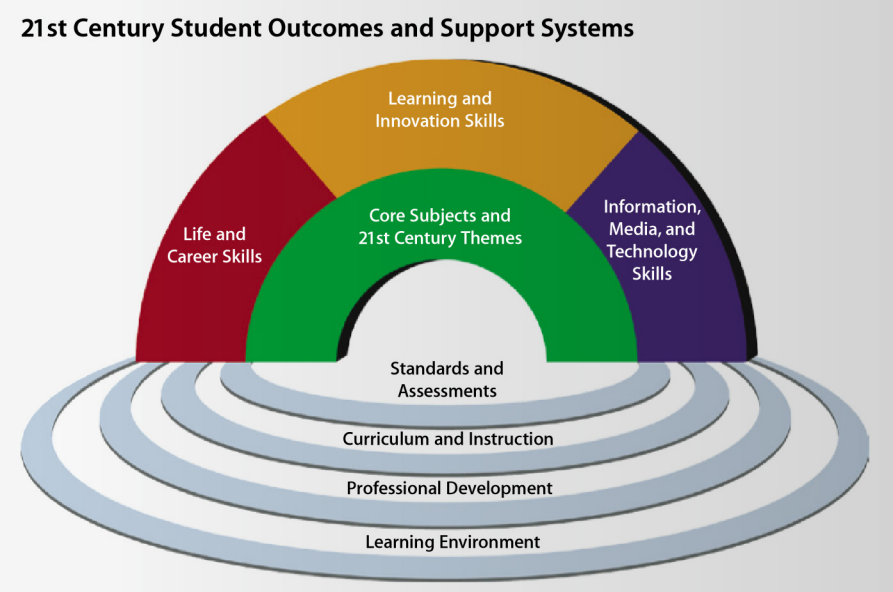

Figure 4: P21 framework for 21st century skills

Core Subjects

- English, reading, or language arts
- World languages
- Arts
- Mathematics
- Economics
- Science
- Geography
- History
- Government and civics

The term "core subjects" is used in the P21 framework to designate the content knowledge that most people recognize as school subjects. While content knowledge has always been a part of schooling, cognitive psychology research on expert problem-solving has helped explain the nature of the content knowledge needed for the 21st century. This research demonstrates that experts have extensive amounts of content knowledge and that they organize this knowledge about important concepts in their field of expertise. This method of organizing content helps them retrieve it when it is needed quickly and with little effort.[15]

Although most learners will not become experts in the fields that they study, it is important to understand that knowing a subject is not just about memorizing facts and acquiring basic skills. It is also about organizing this knowledge in a way that connects it to problem situations. Experts' knowledge organization is acquired in thousands of hours of experience in attempting to solve problems and understanding which facts and skills are useful in which situations. Educational research has suggested that these kinds of connections can also be established in school settings in which students learn facts and skills while they are solving problems.

Developing conceptual structures that are correct and rich requires a deep understanding of a domain. This process can be facilitated by curricula that emphasize depth over breadth so that learners have time to develop understanding. It can also be facilitated by instruction that encourages learners to reflect on their process of learning and their understanding.

Interdisciplinary Themes

- Global awareness
- Financial, economic, business, and entrepreneurial literacy
- Civic literacy
- Health literacy

Interwoven within each of these content areas are several interdisciplinary themes. Although there are many important and interesting interdisciplinary themes, the ones presented here have been identified by the Partnership as areas likely to be increasingly important in the future.[16] They represent emerging content areas that are not typically covered in school today.

These themes are intended to cross content boundaries and should be developed within multidisciplinary study. Economic literacy, for example, contains key social science concepts. And without mathematics and persuasive writing, the effectiveness of any economist would be diminished. These themes are best developed through rich, authentic work that mirrors the work of professionals in the field.

Information, Media, and Technology Skills

- Information literacy
- Media literacy
- Information and communication technologies (ICT) literacy

Also linked to core subjects and interdisciplinary themes is the need for information, media, and technology skills.

Today, students get their information from sources that have not been vetted by the traditional publishing processes. Consequently, they "must be able to recognize when they need information, what kind of information they need, and where to look for it to complete a task successfully. They must also be able to do this effectively regardless of the information's format, source, or location."[17] And they must also be able to judge the quality of the information, its accuracy and objectivity.

Information literacy moves beyond students' ability to evaluate the information they receive to being able to communicate their own understanding and perspectives in a wide variety of media modes, genres, and forms. For example, Web 2.0 tools such as blogs and wikis have put students in the position of being creators as well as consumers of published information.

One example, controversial among educators, is the use of Wikipedia as a research tool. This collaborative, socially constructed encyclopedia can be edited by anyone and thus may contain errors and biases. While some teachers forbid its use for research, others are using it as a tool for helping students become more information literate by having them create and verify their own entries. Students may begin by looking up entries for their own hometown, check them for accuracy, and add something that is missing. This idea of knowledge as the product of students working collaboratively is strongly connected to the way that academic and scientific communities work. It also supports the development of students in providing evidence and argumentation for their ideas.[18]

Learning and Innovation Skills

- Creativity and innovation
- Critical thinking and problem-solving
- Communication and collaboration

Learning and innovation skills are those needed to solve complex problems. They include critical thinking and problem-solving skills, creativity and innovation skills, and communication skills.

These areas have a long history of research. Individual cognition and problem-solving research findings have highlighted the skills that experts use in critical thinking. In addition to an extensive knowledge base of organized factual information, a key finding is that experts monitor their own thinking: they define their learning and problem-solving goals and keep track of their progress toward achieving them. There is evidence that children can be taught these skills and enhance their problem-solving performance.

Creativity and innovation are the processes of developing new perspectives and applying them to specific problems. These skills are thought to arise as problem-solvers reinterpret problems and elaborate on these new interpretations. Research has recently begun to contrast "routine experts," those who efficiently and accurately retrieve a solution for a problem, with "adaptive experts," those who continually evolve new approaches to problem situations.[19] Traditional assessments and schooling tend to emphasize routine efficiency, but in the 21st century, routine tasks will be done by machines or be outsourced to lower paid workers. Research suggests that if learners and teachers are aware of these two different kinds of expertise, and monitor and encourage their development, students can be both efficient and adaptive.

In the 1990s, researchers shifted their focus from studies of individual thinking and began to concentrate on how people solved problems in groups using books, tools, and machines. Instead of studying a single problem-solver in a laboratory or school, they began to study problem-solvers in informal settings and in the workplace. The focus was on how successful groups work together to solve problems using commonly available tools.

Knowing how to participate in groups and use group tools is a critical aspect of learning and problem-solving in the 21st century. In fact, over 80 percent of employers rank collaboration and teamwork as a "very important" skill for those entering the workforce in the 21st century.

Life and Career Skills

- Flexibility and adaptability
- Initiative and self-direction
- Social and cross-cultural skills
- Productivity and accountability
- Leadership and responsibility

Basic subject knowledge and skills are necessary but not sufficient for successful performance in life and on the job. Many additional traits are needed, including taking initiative, being accountable, and being a leader. In recent surveys, more employers rated these applied skills as more important than basic subject knowledge.[20] They also found that most high school graduates and many graduates of two- and four-year schools are deficient in these skills. It is important that schools align their learning environments, requirements, and assessments to promote the acquisition of these skills prior to graduation.

Relevant and Applied Curriculum

"Curriculum is the formal and informal content and process by which learners gain knowledge and understanding, develop skills, and alter attitudes, appreciations, and values under the auspices of that school." [21]

— Ronald Doll

Educators often think of "curriculum" as being limited to the academic goals and standards within each content area, and the books and learning materials that support those goals. According to Ronald Doll, curriculum actually refers to all purposeful activity that takes place within the classroom.[22]

Curriculum that is crucial to 21st century learning must be designed to support active, authentic, and engaged learning. It must also leverage the technologies that are just beginning to make an impact in schools and universities across the nation. With these requirements in mind, the ACOT^2 project has identified six key characteristics for a 21st century curriculum:

1. Involves collaboration and community
2. Is based on authenticity and relevance
3. Leverages real-world tools, resources, and methodologies
4. Incorporates a rich continuum of teaching and learning strategies
5. Is grounded in rich content with a 21st century context
6. Creates linkages to the outside world

1. Collaboration and Community

The ability to function as a member of a team is key in the 21st century workplace. Therefore, it should also be a key characteristic of the 21st century classroom where one stated goal is to prepare students for a productive and successful work life.

It is important to note, however, that it is not only workplace imperatives that recommend a focus on cooperative and collaborative learning in 21st century learning. Cooperative and collaborative learning have long been recognized as one of the most consistent strategies for increased student achievement. For example, in his

recent book, *Classroom Instruction that Works,* Robert Marzano identifies cooperative learning as one of the nine most effective instructional strategies available to classroom teachers.[24]

It is also important to note that the education literature makes a distinction between cooperative and collaborative learning. Generally speaking, cooperative learning is a set of strategies that provide the structure for students to learn and work effectively in small groups or teams. Collaboration is more generally defined as positive interactions during the learning process that build relationships and lead to increases in learning, understanding, and product quality. The importance of understanding the differences is to better understand the relationship between the two: collaboration is greatly enhanced if the skills and processes of cooperative learning are mastered.

In a recent meta-analysis completed by David and Roger Johnson of over 164 studies on various methods of cooperative learning, the Johnson brothers suggest that cooperative learning should have a certain set of characteristics.[25] These include:

- *Positive interdependence.* Members of the group understand that they can only succeed by working together, and rewards and celebrations are based on the success of the group.
- *Promotive interactions.* Rather than compete, members of the group support one another, exchange information and resources, and accept as well as provide constructive criticism.
- *Individual accountability and personal responsibility for group goals.* Everyone in the group takes responsibility for the successful completion of the project and is held accountable for their portion of the work.
- *Frequent use of interpersonal and small-group skills.* Students are taught the various roles that need to be assumed when functioning as members of a team and practice these roles in the context of rich, relevant work.
- *Assessing and refining the functioning of the group.* In formal cooperative learning environments, processes are established to continually assess the quality and effectiveness of group interactions. Each member is responsible for evaluating his or her own contributions as well as those of others.

Recent work on learning communities has extended the importance of collaboration from student-to-student collaboration into teacher-to-teacher and teacher-to-student interactions. With the democratization of information that is taking place and in a world where virtually all information on a topic is available to anyone in real time, the relationships of teachers and students need to evolve significantly. Teachers need to move even beyond the role of facilitators and become collaborators in learning, seeking new knowledge alongside students and modeling positive ways to work and think.

Not surprisingly, technology can play a central role in promoting collaboration in the learning environment. A powerful example of this is the CSILE (Computer-Supported Intentional Learning Environments) project from University of Toronto.[26] Developed by Scardamalia and Bereiter in the late 1980s, CSILE invited students into a knowledge-building environment where they would enter interesting things that they had learned into a shared database. Then, through a series of scaffolded interactions with their information, information contributed by others, and prompts provided by the software, they would refine these interests into researchable questions. While CSILE is still available as Knowledge Forum, many of the functionalities of the original environment can be duplicated using Web 2.0 technologies such as wikis.

Another example of technology-anchored collaboration is Margaret Riel's Learning Circles.[27] This project, now part of the iEarn network, allows student groups in geographically diverse locations to collaborate on curriculum-related projects where both teachers and students work and learn together.

Research Findings Related to Collaboration and Community

While models of student and teacher collaboration have not yet been widely researched, the impact of cooperative or collaborative learning has been well documented. In the Johnson brothers' meta-analysis of over 164 studies on various methods of cooperative learning, virtually all of the studies showed significant positive results.[28] Depending on the strategy employed and whether cooperative learning was compared to competitive or individual learning, the Johnsons recorded average effect sizes ranging from .18 to 1.04. Most of the effect sizes reported would be considered strong effects. Marzano, after completing a similar review of cooperative learning studies, reported an average effect size across studies of .73—an extremely large effect that would account for learning gains of approximately 27 percentile points.

2. Authenticity and Relevance

The concept of more authentic, relevant learning has been bandied about in education since the time of John Dewey in the early part of the last century. Dewey's concept of "learning by doing" was based on his understanding that people learn best when they are actively involved in tasks that have meaning and importance.

Unfortunately, except for a few schools involved in active learning models such as problem-based or project-based learning, most classrooms still focus to a great degree on "exercise-based" work as the basis of student learning. From math worksheets to essays and reports, most of the work assigned to students is destined solely for the gradebook. This raises the question: Are exercises and reports the best way to prepare for a world that values innovation and new knowledge? Are these tasks rich enough to allow teachers to embed other important 21st century skills in the learning process? Recent theorists, such as Fred Newmann, think not.

Fred Newmann from University of Wisconsin defines a set of standards for Authentic Instruction, Authentic Student Performance, and Authentic Assessment Tasks.[29] These standards paint a picture of authenticity and relevance in practice. Newmann's standards are organized into three areas:

- *Construction of knowledge.* Students must apply the facts, concepts, and skills that they learn into the construction of some knowledge product or new understanding.
- *Disciplined inquiry.* Students must use disciplined inquiry; that is, develop an adequate base of knowledge and an in-depth understanding of the content and methods of the discipline, which are exhibited through complex communication of ideas central to the discipline.
- *Value beyond school.* The performance must have value beyond the school; that is, the work must have meaning or value that transcends the student-teacher relationship and is not simply used to rate the performance of the student for grading purposes. This value may be a result of sharing the work in a meaningful way with an audience outside the classroom. It may also have value simply because the topic and product are personally valued by the student. Or it may be that the product or task closely mirrors the kind of work done in the real world and that relationship is clearly evident to the student.

The most challenging of Newmann's standards are those for Value Beyond School. These standards would have been extremely difficult to address in the past, but with the advent of new technologies such as wikis and blogs, students can now communicate with audiences outside the school in safe and efficient ways. For example, technologies such as iMovie and GarageBand allow students to create products that can be shared with a host of audiences in their schools, communities or even globally. Projects such as those found on the iEarn website and web-based technologies such as SurveyMonkey or Zoomerang allow students to create and collect survey research with real subjects and real audiences. In the 21st century curriculum, authentic, relevant work is finally scalable.

Integrated within Newmann's model for authentic learning is the concept of Deep Learning. Noel Entwistle from the University of Edinburgh contrasts deep, strategic learning with shallow, apathetic learning.[30] (Note that the entries in the table are not always parallel.)

Deep Learning	Shallow Learning
Relating key concepts	Routine memorizing
Using evidence and developing schema	Following rote procedures
Focus is on growth and understanding	Focus is on minimum requirements
Intention is to seek meaning for yourself	Intention is to get it done

Deep Learning is a style of learning that comes more naturally to some students than others. In fact, the literature on Deep Learning has many similarities with the literature on self-directed learning, a 21st century skill. But habits of Deep Learning can be nurtured in all students. Deep Learning requires deep teaching. Teachers must give students challenging tasks that require them to wrestle with core concepts in the curriculum and the time to do so.

Research Findings Related to Authenticity and Relevance

While randomized studies that demonstrate the power of relevant, authentic learning have yet to be conducted, a body of compelling correlational research hints at the power of this instructional theory. Newmann has applied the authentic learning framework and assessment tools in two compelling studies. One is an analysis of the role of authenticity in promoting student achievement in school reform projects over a five-year period,[31] and the other is a study of the relationship between authentic work and student achievement in 100 classrooms in the Chicago Public School system.[32]

In each of these studies, Newmann found a strong relationship between the authenticity of the work assigned in classrooms and student achievement. In the Chicago study, for example, multiple assignments were gathered from over 100 teachers randomly selected from schools in grades 3, 6, and 8. The assignments were analyzed using the standards and rubrics for authenticity described above. The state assessments in reading and math and the Iowa Test of Basic Skills were used, controlling for race, socioeconomic class, gender, and prior achievement. Newmann found that students in classrooms where intellectually rigorous, authentic work was assigned gained 20 percent more than the national averages. In classrooms where assignments were less rigorous, student growth was approximately 25 percent below national averages.

3. Real-World Tools and Methodologies

If student work is to be truly authentic, the tools and methodologies that are used to do that work need to be authentic as well. As the tools of professionals become increasingly digital, they become more economical for use in education.

For example, word processors, spreadsheets, databases, and presentation software are ubiquitous in high schools around the nation. But other tools are available as well. Professional historians, for example, seldom rely on textbooks for their information. They piece together the stories of history from firsthand documents, letters, and other artifacts. Through resources such as the Library of Congress, the Smithsonian, and others, these same artifacts are now available to anyone with a digital device and an Internet connection.

For example, oceanographers make use of real-time data from buoys scattered across the oceans of the Earth. Students can now access that same data and conduct analyses that parallel those of professionals. Movie editing software, once prohibitively expensive and requiring massive computer systems to run, is now included for free with many computers purchased by schools. Students can now use the same resources for learning that once were the exclusive province of the professional and report the results of their learning in a variety of media reflective of the world in which they live.

One of the major hurdles that must be overcome if students are to have access to the tools and practices of professionals is the lack of knowledge of many teachers of the real-world applications of the content that they teach. Many mathematics teachers at the high school level, for example, have been classically trained in mathematics. In many universities, this means that their training has been steeped in theories and algorithms with very little connection to practical applications.

Just as students need scaffolding to develop 21st century skills, teachers may need scaffolding to begin to identify the applications of the content they teach and to construct real-world problems and projects related to that content. For example, providing math teachers with access to architects or civil engineers can provide the impetus needed to create those projects. Even providing students, through email or other Web 2.0 communications, with access to professionals can sow the seeds of real-world applications within the classroom.

The opportunity for the use of real-world tools in the curriculum is as new as many of the tools themselves. Solid research documenting the impact of these tools on student learning is sparse. There are hints in early research, though, of the potential power of these approaches. In a review of the use of databases of firsthand historical resources in the curriculum, for example, Michael Berson from the University of South Florida reported that studies have "demonstrated increased academic achievement, motivation, self-directed thinking, self-initiated activity, construction of meaning, analytical analysis, and increases in collaborative peer interaction."[33]

Research Findings Related to Real-World Tools and Methodologies

In a series of research studies conducted with students using Geographic Information Software (GIS) to study science and geography, GIS was found to strengthen problem-solving skills, increase geographic knowledge, and encourage spatial analysis. In two of these studies, it was demonstrated that despite the use of these professional tools resulting in less coverage of content breadth, the depth of coverage consistently resulted in similar or better performance on factual tests and exams.[34] The use of data

collection "probes" has been linked to increases in the ability to interpret data and decreases in student misconceptions in science.[35] Despite the infrequency of use in today's schools, the use of professional tools in the curriculum shows great promise.

4. A Continuum of Teaching and Learning Strategies

The best teachers have always had a variety of "arrows in their quiver" when it comes to teaching and learning strategies. The value of diverse teaching and learning practices is that they can be applied depending on the content. For example, there are times when a lecture or demonstration is the most efficient way to provide students with the information they need. But as access to information becomes more transparent, the need to lecture diminishes and new practices can be developed.

Some of these practices—the use of project-based learning, for example—are established and familiar to most educators. Some new practices, however, are only now being conceived and refined. Online learning has been widely available for less than 10 years. Video and audio podcasts of classes—and even of entire courses—are now available from iTunes U on the iTunes Store. Leveraging these resources and orchestrating these new teaching and learning practices are the challenges for teachers today.

Additionally, as more data becomes available to teachers, they are now better able to diagnose individual students' needs and make better decisions about what will help individual students learn. This ability opens up a whole new range of possibilities for personalizing teaching to meet the abilities of each learner. Options include small group projects and investigations, WebQuests, just-in-time video lessons, and podcasts that integrate lecture content with slide presentations.

Never before have there been as many options for teaching and learning available to classroom teachers. Where technology resources are sufficient, innovative classroom teachers are radically altering their roles within the school as they move from being the primary source of information and direction to acting as a coordinator of purposeful activity that matches student learning needs with available resources, thereby promoting self-directed learning behavior.

Research Findings Related to Teaching and Learning Strategies

Most of the learning and teaching strategies discussed above have their own bases of research. Some, like authentic learning and assessment, have strong correlational studies supporting them but not much in terms of randomized controlled trials, the gold standard of research. Project-based and problem-based learning each has a considerable body of research behind it, but the results in these studies vary greatly depending on the specific content and process employed.

Some of the strategies are too new to have bodies of research. For example, only a couple of studies have looked at the efficacy of WebQuests in improving student achievement. In one of these studies, a control group in Texas outperformed the treatment group, which participated in a WebQuest on the Texas Revolution.[36] But, as the author notes, the control group did not use a traditional, textbook-based approach to learning. They participated in a project that represented that span of Texas history through visual symbols, a compelling group learning approach that seemed more steeped in content and critical thinking than was the WebQuest.

One lesson that can be learned from much of the research on new, technology-supported learning tools and strategies is that their effectiveness is more dependent upon the quality of the content than on the medium. Harold Wenglinsky, known

in education technology circles primarily for his landmark study on the subject, conducted one of the more compelling studies on the impact of varied teaching practices in the classroom.[37] It demonstrated that the students of teachers who used technology for higher order uses such as simulation and inquiry outperformed students whose teachers did not use technology or used it for drill and practice. In the study, Wenglinsky noted that the students of teachers who used varied teaching strategies, hands-on learning, critical thinking activities working with real-world problems, and so on did significantly better on the NAEP mathematics test than those students of teachers with more limited instructional repertoires.

5. Rich Content with a 21st Century Context

As previously noted, 21st century skills are an imperative that schools cannot ignore. Some of these skills can be taught directly, then integrated within the content areas; critical thinking skills are one example. Some require specific environmental, instructional, and organizational changes to provide scaffolds for students as they build new, more productive learning strategies. Self-directed learning is an example here.

Some skills need to be integrated into content and involve changing the context of the content being taught more than involving specific knowledge and skills. A good example here is global awareness. Global awareness can be incorporated into virtually all subject areas by developing the skills, knowledge, and attitudes that will help students learn to operate in a global context.

Several principles should guide the selection of content and context in 21st century learning. First, when possible, educators should err on the side of depth versus breadth. As described earlier in this report, Deep Learning results in student achievement that is the same or better than rote tasks on assessments of rote learning. But Deep Learning also leads students to the understanding of core concepts and principles in the content area and, if combined with authentic, relevant work, allows the student to develop the higher order skills defined in the P21 framework.

Second, schools must link standards across content areas through the creation of rich, multidisciplinary units or projects. The real world is multidisciplinary. Any field of study—journalism, computer science, environmental science, accounting, and so on—has aspects of language, writing, science, math, and communications. Assigning multidisciplinary work better prepares students for this reality.

In addition, assigning rich, relevant product-oriented work is often inefficient in a departmentalized context. Recently, in California, students participated in a three-week unit developing a travel website with its theme based on the California Standards for ancient Greek history. If the only standards to be addressed were those history standards, the amount of time spent on the unit might have seemed excessive. But the teachers designing the unit incorporated math instruction for pricing, money conversion, and time/distance calculation; language arts instruction for persuasive and descriptive writing; technology standards for use of graphics and web tools; and a host of 21st century skills. The unit increased their efficiency in covering the curriculum.

Finally, schools must infuse the curriculum with a forward-looking context. A teacher in Virginia studying weather patterns in an earth science unit had students collect real-time data from buoys in the Caribbean Sea and Atlantic Ocean to look for changes in currents and temperatures that might be impacted by global warming. Students used those data in concert with satellite images of water vapor to prepare an advocacy report to send to local legislators. Involving students in the issues of today and doing

so with the tools of professionals in the field can provide students with a sense of the importance of the content they are studying and its linkage to the world around them.

Research Findings Related to Rich Content with a 21st Century Context

Several bodies of research are linked to the topic of rich content with a 21st century context. First would be the research already discussed in an earlier section on assigning rich, authentic work to students. Studies also suggest that in authentic problem-based learning environments, students develop flexible knowledge, linked knowledge that is more easily activated and transferred to novel situations, more effective problem-solving skills and, perhaps most importantly, build skills of metacognition. Metacognition, the ability to monitor the quality and effectiveness of one's own thinking, is a key to critical thinking, self-directed learning, and other key 21st century skills.

6. Linkages to the Outside World

Another defining characteristic of 21st century learning is linkages to the world beyond the classroom. These linkages serve several purposes. First, linkages with local community groups, small businesses, and institutions such as local museums and historical societies, can provide outlets for authentic student work. Second, these linkages can provide additional opportunities for students to collaborate and to act as part of multidimensional teams. Third, these linkages can provide positive role models for students. Interacting with real scientists in an online project, for example, can give students positive insights into professions and professionals alike. Finally, these connections can help students understand their position in relationship to others in their community, nation, and the world, expanding their sense of place and connectedness.

There are several levels at which linkages to the outside world can become a regular part of the student experience. First, simply assigning work on topics where the student has had some say in the development of that topic or where the topic is of obvious interest and importance to the life of the student outside the classroom establishes a link to that outside world. While studying immigration issues in American history, for example, asking students to research their own family's immigration using tools such as the Ellis Island website or interviews recorded with elder members of their family relates the learning to the life of the student.

A second type of link can be a simulative one. Many online projects offer students the opportunity to emulate the work done in the outside world through rich simulations. In the IMMEX project from UCLA, for example, students studying genetics in the seventh grade can play the role of a genetic detective using actual lab results to try to determine which of three claimants is the twin of a wealthy heir. Perhaps one of the best-known education simulations of the 1990s was the Jasper Woodbury series from Vanderbilt that allows students to solve real-world problems in a video-supported, simulated environment.

The third and most powerful mode of connecting to the real world is through genuine engagement with the world outside of the classroom through joint projects or through authentic projects with a real-world audience. For some time, theorists have discussed the potential for increases in motivation when students are provided with opportunities to do work that has an audience outside of the classroom. Historically, however, this has been difficult to organize at scale in the insular classroom of the past.

Today, through email and Web 2.0 technologies such as wikis, blogs, and podcasts, it is now possible to engineer collaborations between students and virtually any other individual or group: students of other nations, experts in a chosen field, university staff, and more. At the entry level, pre-existing projects such as those within iEarn are here today, allowing teachers and students to join global writing or science projects in a safe environment pre-populated with schools across the globe. More advanced teachers are relying on their own visions to leverage the web and new technologies to envision new, exciting, and engaging projects that bring the world into their classrooms on a daily basis.

Research Findings Related to Linkages to the Outside World

Early studies of the IMMEX simulation environment documented improvement in problem-solving accuracy across problem sets and, more importantly, increases in metacognition.[38] A large study of the Jasper Woodbury simulation found that while basic achievement was the same in students using that program versus controls, the Jasper Woodbury group outperformed controls on more advanced problem-solving skills and had more positive attitudes toward mathematics.[39]

Informative Assessment

"When our students understand that we value their learning more than their test scores, then, maybe—just maybe—they will stop asking the short-sighted question and embark on their own learning journeys."[40]
— Marge Scherer, ASCD 2007

Informative assessment guides and facilitates learning. Teachers can use informative assessment to make instructional and curricular changes intended to yield immediate benefits for students. Likewise, students can maintain their work as demonstrations of their learning and use reflective and metacognition practices for continuous and deep learning. A continuous or frequent stream of data can be used to monitor outcomes with the explicit purpose of ensuring a quality journey and timely arrival at the destination.

To understand informative assessment, consider the student as gamer. She is motivated to play because she gets feedback every few seconds. That feedback entices and enables her to "stay in the game," provided she has learned from prior experiences, monitors the current situation, pays attention to the constant feedback, and reacts quickly enough. "Failure" simply provides her a quick break before she gets back into the game—with renewed effort, new data, and new resolve to achieve new plateaus.

Another example of informative assessment might be the comments a student gets back from a circle of learning where peers critique the storyline and flow of her early version digital story. Here the goal is twofold. First, the student is provided with feedback so she might revisit, review, and improve current work (self-regulation of learning). Second, the intent is to provide information for responsive teaching so the next action by the teacher can be differentiated based on actual student needs and interests. The result is meaningful feedback.

Through informative assessment, students, teams of learners, and teachers can use evidence of current progress to adjust, adapt, or supplement the learning experience. Informative assessment serves as a GPS, helping all to see the current position relative to the destination, while judiciously avoiding judgments.

The type of data collection for informative assessment varies considerably, but might include student journals and self-assessments, peer reviews, teacher observations, student-teacher conferences, interim product analysis (based on rubrics), and others. Informative assessments are conducted during the learning process before any summative evaluation can occur and are typically ongoing and often not recorded.

Summative assessment, on the other hand, is intended to evaluate progress to date. It may take the form of the grade a student earned on a classroom assignment, a measure of program effectiveness, or a determination about whether or not a school has made adequate yearly progress. These are referred to as assessments of learning. While summative assessments are administered for the purposes mentioned, they can serve dual purposes and be used formatively as well.

As student work becomes more collaborative, technological, and inquiry-based, students are increasingly learning in online, informal, and team settings. As such, feedback is often generated by other participants working in the same virtual learning spaces and through joint development of wikis, blog responses, text messaging, verbal interactions, or video/audio responses. This is also the case when learners produce multimedia products, publish to the web, and then peers, instructors, co-developers, parents and family, experts, and others provide feedback. This translates into a critical need for self-regulation of learning by students, coupled with clarity of goals.

Research Findings Related to Informative Assessment

According to Dr. Dylan Wiliam of the University of London, research findings from over 4000 studies indicate that it is informative and not summative assessment that has the most significant impact on student achievement.[41] The research on informative assessment in learning stresses the key role of meaningful, timely, and continuous feedback on Deep Learning. For the assessment to be meaningful and timely, the student or team must be clear not only about the learning goals but also on the criteria by which the learning will be measured.

A student's or team's thinking should be made visible through active learning strategies such as discussions, argumentation, papers, journaling, reflections, peer reviews or critiques, quizzes, response systems, and so on. Researchers also stress that such feedback must emphasize understanding of Deep Learning of content and process—not just memorization or procedures.[42] Such feedback is most effective when students are provided the opportunity to use the data to revise their thinking and their work while the unit is still in progress—in other words, self-assess.

Researchers are also finding that opportunities for students to work collaboratively can increase the quality of the feedback. Today such opportunities can be augmented through technology and web tools. Similarly, it is important that the teacher approaches informative assessment with the intent of improvement rather than evaluation. That translates into a mindset where the teacher is continually seeking to rethink and adjust her teaching to meet the needs of learners. Whether the learning goals are self-initiated or established by the school, informative assessment through such feedback and revision cycles is a powerful aspect of learning. The use of effective informative processes in school establishes strong models for the student to use in more informal learning settings.

Summative assessment also plays a role in student learning, for it ultimately acknowledges whether or not the student or team has attained the goal. Doug Reeves recommends designing a "student-centered accountability system."[43] If informative assessments are effective, the summative assessment will be a formal, culminating affirmation of the accomplishments and, in some cases, an opportunity for public performance, publication, or implementation of the student's or team's work.

Two new elements of summative assessment are being reported in the research community. One is the issue of performance assessments augmented by scaffolds. Roy Pea discusses the need to recognize that many of the technology-based scaffolds such as web access to resources, web access to experts, access to productivity tools, and others should be fully accessible to students in summative assessments.[44]

The second issue is the need to recognize a second type of learning beyond what the individual student is expected to attain by herself—that is, learning that is collaborative in nature that cannot be accomplished by a single individual. In this case, the assessment does review the individual's role in the teamwork, but is largely focused on the outcomes from the team effort. According to Kai Hakkarainen and colleagues, this moves beyond the acquisition metaphor for learning to the participation and knowledge creation metaphors.[45]

A Culture of Innovation and Creativity

"Like short skirts, innovation has traditionally swung in and out of fashion: popular in good times and tossed back into the closet in downturns. But as globalization tears down the geographic boundaries and market barriers that once kept businesses from achieving their potential, a company's ability to innovate—to tap the fresh value-creating ideas of its employees and those of its partners, customers, suppliers and other parties beyond its own boundaries—is anything but faddish. In fact, innovation has become a core driver of growth, performance and valuation." [46]
— Joanna Barsh, Marla M. Capozzi, and Jonathan Davidson

Businesses have long recognized innovation as the fuel that drives the global economy. In fact, the new competitive frontier in the world of work is place-based innovation—the ability to innovate again and again within one environment. What this means for education is that learning, creativity, and innovation skills are critical to future success in life and work and should be an integral part of a 21st century curriculum.

Some experts argue that systems can be designed and deployed that produce innovation while others argue that systems squash innovation, and the answer lies instead in creating a culture that supports and advances innovation at its core.

Those who have successfully created cultures of innovation and creativity suggest that one key is to abandon efficiency as a primary working method and instead embrace participation, collaboration, networking, and experimentation. This does not mean that focus, process, and discipline are not important; just that innovation and creativity require freedom, disagreement, and perhaps even a little chaos—especially at the beginning.

In this way, fostering innovation and creativity is often counterintuitive to the beliefs and practices of efficiency-minded business managers and administrators. According to Stanford professor Richard Sutton, creative, "weird" ideas work because they provide three key things: an increase in the range of an organization's knowledge, the ability for people to see old problems in new ways, and an opportunity to break from the past. On the other hand, he warns that creative environments are often "remarkably inefficient and terribly annoying places to work."[47]

This suggests that teachers should attend to and scaffold students' creativity by providing opportunities for students to engage in deep, complex thinking, employ strategies that are unorthodox and nonlinear, and to explore ideas that are new and even radical. Moreover, these opportunities should exist in an environment that is positive and upbeat, tolerant of failure, provides tools for experimentation, and has little overt evaluation of student work.

Borrowing Models from Business

In addition, schools should consider emulating models of managing innovation from the business world. Management expert Peter Drucker offers one such model.[48] Drucker suggests that there are seven windows of opportunity that open up

possibilities for innovations. His list includes unexpected occurrences, incongruities, need for efficiencies, industry/market changes, demographic shifts, changes in perception, and new knowledge.

For example, there is currently an incongruity between the contemporary technology tools used by adolescents, such as cell phones, and the high percentage of school districts that ban those very tools from use in schools. Given the large number of students who are disenfranchised from school, this incongruity provides a window of opportunity for educators to re-engage students and catalyze their innovation and creativity through creative use of technologies currently banned.

Another Drucker-style window of opportunity is the positive change in perception recently by the public about the integration of 21st century skills into schools. This represents an incredible opportunity for educators to not only integrate technology into academic standards, but to embrace the 21st century skills as operating principles for their own careers. This would involve a recasting of professional educators as co-stewards—with students and community—of a forward thinking, high-tech, adaptive, 21st century learning system.

Another model of managing innovation in business arises out of the open-source business model. Open source is a set of principles and practices on how to write software that is openly available to anyone who would like to add to it, change it, or use it. Open source is also culture in which giving back to the community is a core value. In businesses based on an open-source model, innovations and creative ideas often come from community members external to the business, which requires radical new techniques for process management and decision-making, among other things.

Mitchell Baker, chairman and former chief executive officer of Mozilla—developer of the very successful open-source browser, Firefox—is a pioneer of the participatory open-source model of collaboration to manage innovation that she introduced at Mozilla to evolve Firefox.

In a recent article, Baker discussed how this works at Mozilla. "For some things at the center, we must have extreme discipline. If you're touching code that goes into Firefox, the process is very disciplined. But there are lots of areas for participation—whether it's building an extension or localizing the product or building new products—that don't need that degree of discipline. And a key point is for people to 'own' what they are doing, not in a financial or legal sense but in an emotionally committed sense that gives them a chance to decide, 'I'm excited about this. I want to do something. I want to write an extension. I want to go tell people how to do this.'"[49]

When asked about how the model specifically enables innovation, Baker cited three things: "Sometimes, just giving people permission does wonders… Second, we create scaffolding for people to work from, so that even if we're not innovating ourselves, other people can… Third, we've assembled a set of people here who are really motivated by seeing other people do interesting things. So if somebody appears, out in another community, doing something interesting, we don't have a not-invented-here culture; we just say, 'Wow!'"

Still, open-source collaboration is not without its challenges. "There are days when somebody's done something and you wonder, 'What were they thinking?'" said Baker. "At that point, you have to look really carefully and evaluate what's just uncomfortable and what really must be fixed. And then you try to keep that latter category to a minimum. A healthy community will do a lot of self-correction."

Educators should look closely at these and other business approaches to see where there might be openings for innovation within their own schools.

Research Findings Related to Innovation and Creativity

Up until the 1990s, the creativity literature looked at creative individuals to the exclusion of creative situations. In 1996, Teresa Amabile updated her 1983 book on creativity to include this new focus: the creative situation (the creative individual within a social or cultural context, the creative team, and/or the creative organization).[50] Research on social factors related to creativity suggest it is influenced in the individual by birth order, family relationships, early exposure to cultural diversity, environments that encourage autonomy and self-directed learning, and exposure to a creative model within that particular work area.

Research also tells us something definitive about the impact of motivation on creativity. Findings suggest that intrinsic motivation is a necessary component to creativity. This is due, in part, to the fact that it requires genuine interest in the topic to sustain the hard work and perseverance required to be creative. Extrinsic motivation, on the other hand, usually diminishes or extinguishes creativity. The only exception is when the extrinsic motivation is perceived as a bonus rather than as the reason for the creativity.

Similarly, the element of evaluation shifts motivation from the intrinsic to the extrinsic, which in turn undermines creativity. The research is not yet clear on the impact of competition, deadlines, self-evaluation, and rewards on creativity. While further research is needed, there are indications that the modeling of creative solutions can further creativity.

Organizational interests in innovation are driven by the need to constantly reinvent. The factors related to innovative environments include group autonomy, group socialization, mentoring, knowledge transfer, innovation norms, innovation sequence, cultural valuing of innovation, and a culture of risk taking.[51] In addition, there seems to be a strong correlation between levels of innovation and job satisfaction.

Social and Emotional Connections with Students

"Reports from the young learners... highlight the dynamic, highly social, and self-sustaining processes that are an important aspect of knowledge and identity development... we should expect interest in learning to originate within and outside school and that adolescents have a significant role to play in sustaining their own development. [52]

— Bridget Barron

Social and emotional factors profoundly affect student engagement and motivation as well as student perceptions of relevancy of task. All of these elements have an impact on learning.[53] For example, when students lack social and emotional connections to learning, educators, schools, and their peers, it often leads to behavior issues or disengagement, which inevitably leads to declining achievement and, in the worst cases, students dropping out of high school.[54]

Schools are communities, and care can be taken to ensure that each and every student has a purposeful connection with at least one adult in the environment. That adult engages the student in conversation about life and their learning and is a resource for the student. This strategy can be accomplished in myriad ways, but because it is a critical prerequisite for student success, it cannot be left to happenstance.

Having a social and emotional connection supports engagements and, on the surface, engagement as a prerequisite for learning seems obvious and straightforward. However, engagement is more complex and is typically defined in three ways: behavioral motivation (student participation in learning tasks); emotional engagement

(reactions to teachers, other participants, activities in the learning task, and school as well as student attitudes, interests, and values); and cognitive engagement (the willingness to exert the effort that the task requires).[55]

Looking at engagement across these three areas reflects the complexity of students' experiences in the classroom. Research studies indicate that student perception of relatedness to teachers, parents, and peers uniquely contributes to emotional and behavioral engagement, as does a student's "feeling secure" with teachers and having a feeling of "belonging," as defined by an individual's sense of being accepted, valued, included, and encouraged by others. Similarly, a positive association has been established between students' need for competence and their engagement—behavioral, emotional, and cognitive.[56]

One of the key elements of learning, both in school and beyond, is student motivation. What determines a student's choices, persistence, and efforts in learning? The answer to this question is social and emotional influences.[57] Researchers generally agree that learning is inherently social—it happens in the context of interactions and relationships with teachers, peers, family, experts, and others.[58]

Social interactions provide tremendous opportunities for students to deepen learning. They find kindred spirits who fuel joint explorations and productions, reinforce understandings, and provide divergent opinions and clarification of understandings as discussions ensue. In many cases, social interactions enable levels of learning that simply wouldn't be possible for students to accomplish on their own. Successful leveraging of such opportunities requires some degree of social and emotional maturity on the part of the student—especially when interactions occur outside the school environment.

The school has several roles to play in building social and emotional connections among students. The obvious role is the establishment of learning environments that promote healthy social and emotion interactions. Educators have found that introducing healthy social interactions such as learning circles, collaborative learning, and active learning strategies into learning does increase academic performance.[59] Ultimately schools should be building self-direction in learners, enabling students to learn successfully in informal settings outside of school.

Actions at the classroom level that directly affect students' cognitive, behavioral, and emotional engagement include: teacher support (interpersonal and academic); connections with peers (idea discussion/argumentation, peer critiques); classroom structure (one that ensures respect, high academic challenges, and socially supportive environments); autonomy support; and task characteristics (the nature of the task, including its authenticity, the level of interest and/or ownership it generates in the student, the opportunities it presents for collaboration, its level of cognitive complexity, linkages to the real world, and so on). In addition, student perceptions of work and norms established by teachers were positively correlated with behavioral, emotional, and cognitive engagement.

One example of a school that is implementing many of these best practices is High Tech High, a charter high school in San Diego, California. High Tech High is at the top of its game with respect to academic achievement, critical thinking and problem-solving, student engagement, and the percentages of graduates who go on to succeed at higher education institutions. The school attributes its success to three key principles all interwoven into the fabric of the school: personalization, adult world connection, and common intellectual mission.

The school engages the students socially, emotionally, and cognitively—school leaders have come to understand, through research and practice, that the three are intrinsically interdependent.[60] One of the ways the school ensures those connections is through the assignment of a staff advisor to each student. The advisor monitors the student's personal and academic development and provides a point of contact for the family. This caring adult matters tremendously to the student's success in school by socially and emotionally personalizing the learning environment. In the role of mentor, the advisor knows if the student is in school each day, is there to celebrate successes, and generally serves as an advocate.

Research Findings Related to Social and Emotional Connections

The literature on social and emotional engagement stems back to Vygotsky's view that the process of learning is at once individual and sociocultural, and includes research from the cognitive, educational psychology, and social sciences.[61] Researchers generally acknowledge that socialization results in attitudes, values, and cognitive and linguistic skills—all necessary tools that children and adolescents use as they learn.

Recent research summaries also suggest that social and emotional competencies do make a positive difference in student learning. The Collaborative for Social and Emotional Learning (CASEL) announced preliminary results from a study that summarizes the impact of social and emotional competence across 207 research studies. They report that, on average, students in programs that addressed social and emotional competencies outperformed control groups academically by 11 percentiles.[62]

The authors of the book, *Building Academic Success on Social and Emotional Learning: What Does the Research Say?,* agree, reporting that social-emotional competence predicts academic achievement and, conversely, antisocial behavior correlates highly with poor academic performances.[63]

Jennifer Fredrick's and her colleagues' recent article on student engagement offers context for the discussion around declining academic achievement and disenfranchisement of students from schools.[64] The article discusses a multifaceted construct of engagement that clearly links social competence to higher levels of learning and emotional competence to higher levels of learning. A look at high school reform across the country is synergistic with the literature on student motivation and engagement.

There is sound research to suggest that to succeed, school reform must address social and emotional competencies.[65] Bridget Barron of Stanford University goes a step further. She provides a qualitative look at student engagement in students who are using informal learning in combination with formal learning in schools to accomplish specific learning goals.[66]

Ubiquitous Access to Technology

"Our nation's education system must join the ranks of competitive U.S. industries that have made technology an indispensable part of their operations and reaped the benefits of their actions." [67]

— ISTE, P21, SETDA Report

Despite the strong presence of ubiquitous technology in students' lives, a gap exists between teenagers' use of technology and the use of technology for teaching and learning.

When Mark Weiser coined the term "ubiquitous computing" in 1991, he envisioned that "the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable."[68]

Many schools have determined that the way to increase engagement, improve student achievement, and establish digital equity is to provide each student with his or her own notebook computer. This practice enables students to weave the technology into their learning, both in school and out of school, leveraging it for learning, thinking, creating, researching, and publishing; in short, for their daily work of developing critical 21st century skills.

Also at the core of today's ubiquitous technology is a collection of new generation web-based tools and businesses that form a "participatory web."[69] Many of these tools are free. Many are social in nature and promote self-expression. Many allow multiple users to participate by editing, commenting, and polishing a document collaboratively rather than working alone. In some ways, both the tools and the products created with them can be considered works in progress, available for anyone to contribute to, ad infinitum.[70]

About 96 percent of students with online access report using at least one social networking technology. "Online social networking is now so deeply embedded in the lifestyles of tweens and teens that it rivals television for their attention," according to a study done by Grunwald Associates, LLC in 2007 in cooperation with the National School Boards Association.

Students identified by this study as nonconformists—students who step outside of online safety and behavior rules—are particularly drawn to social networking. According to the Grunwald report, "These students are on the cutting edge of social networking, with online behaviors and skills that indicate leadership among peers."[71]

Thirty-three percent of all students are nonconformists, meaning in this study that they report breaking one or more online safety or behavior rules, such as using inappropriate language, posting inappropriate pictures, sharing personal information with strangers, or pretending to be someone they are not. Yet they demonstrate a high level of 21st century skills, including communication, creativity, collaboration, and leadership skills, and technological proficiency. At the same time, they are more likely than other students to have lower grades, which they report as a mix of Bs and Cs.[72] This latter finding reminds us that student achievement may come in many forms and that current methods of assessing student achievement may be too narrow in their focus.

Another population that has much to gain from ubiquitous technology and social networks for learning is youths with disabilities. The National Center for Technology Innovation (NCTI) sees these technologies as great equalizers. "Youths with disabilities, already at risk for being left on the educational and social sidelines, can through social media and these emerging communications technologies, connect with the world in ways that have not been possible before."[73] NCTI points to Brigadoon, an island developed in Second Life by a researcher as a support group for users with Asperger's Syndrome, and the collaborative efforts to make multi-user games accessible to gamers who are visually impaired.

Ubiquitous Technology: A Gap with Teaching and Learning

Despite the strong presence of ubiquitous technology in the lives of students, a gap continues to exist between teenagers' use of technology and schools' use of technology for teaching and learning. However, one positive sign is the growing interest in 1 to 1 learning programs, where students and teachers have 24 by 7 access to a notebook computer and Internet access. In 2003, Quality Education Data (QED)

reported that 4 percent of U.S. school districts had started 1 to 1 programs. According to America's Digital Schools 2006, since 2006 more than 24 percent of school districts are in the process of transitioning to 1 to 1.[74]

1 to 1 Programs Work

Though empirical research is limited on the effectiveness of 1 to 1 programs on student achievement, districts and states report promising results. Students in 1 to 1 environments show greater independence and self-directed learning. They are more engaged and motivated, with significant improvements in attendance and have fewer discipline problems.[75]

As a result, educator experts increasingly have the view that 1 to 1 programs can be a critical component of preparing students for the future. As U.S. Secretary of Education Margaret Spellings noted in a December 2006 speech to business leaders, "Technology can provide a platform to transform education to meet the demands of the 21st century. With education so crucial to our country's future, we must focus … energy, effort and investment into transforming this critical sector."[76]

Carla Beard, chair of the English Department at Connersville High School in Indiana, has said, "If someone were to invent an Engagement-o-meter, our kids would zoom off the top end, and their teachers would not be far behind. We are seeing kids who WANT to take notes. We are seeing kids who were once willing to take a zero and just not do an assignment but who now complete it because a computer is involved. Just today I thought someone was surreptitiously online during my lesson. I asked him to turn off his monitor. He did, but he also said, 'I was at the dictionary site looking up a word.' And he was. Wow!"[77]

An increasing number of schools and school districts are experiencing the reality of such observations after implementing 1 to 1 programs. In Maine, for example, 33,000 seventh and eighth graders enrolled in a 1 to 1 program improved their scores in language arts, math, and science. Having used notebook computers all four years of high school, twelfth grade students scored higher than 85 percent of their peers in all five core subjects of the last Maine Educational Assessment.[78]

While use of notebooks for learning is on the rise, most districts remain cautious about the use of mobile technologies other than computers in the classroom, such as cell phones and iPod players, often prohibiting use during school hours. Many districts are also locking down the social networking capabilities of Web 2.0 tools, concerned about issues of safety and distraction.

It is interesting to note, however, that in spite of this lockdown in schools, students report that one of the most common topics of conversation in social networking is education. Almost 60 percent of students who use social networking talk about education topics online and 50 percent talk specifically about schoolwork.[79]

What impact can ubiquitous technology have on teaching and learning? What is pedagogically possible when these tools and social environments are made available to students? Two trends are shaping 21st century learning.

First, the volume of both new and old content is coming online at a staggering pace.[80] The sheer quantity of stored information in the world is growing at a rate of 30 percent per year, which means it is doubling every three years.[81] Teachers' and students' ability to use that knowledge effectively and deliberately is of the highest importance.

Second, the creation of content is becoming increasingly collaborative. Almost all software applications on the market today have collaborative tools built in. "Right now, teachers are employing blogs and wikis in ways that are transforming the curriculum and are allowing learning to continue long after the class ends."[82]

These trends make possible new models of learning, allowing students to do a substantial amount of learning outside of school and collaboratively in peer-to-peer or small group networks. In "The Educators Manifesto," Robbie McClintock describes three of these models:[83]

- *Connecting to the world.* "Communications technologies have the potential to change schools and classrooms from isolated places with scarce access to information environments with rich connections to the world and all its ideas."[84]
- *Multiple representations of knowledge.* "Multimedia and multiple representations of knowledge make it increasingly evident that the work of thinking can take place through many forms—verbal, visual, auditory, kinetic, and blends of all and each."[85]
- *Augmenting knowledge.* Digital tools designed to "augment human intelligence—from digital calculators, word processors, databases and spreadsheets to very complex modeling, statistical, and graphical software—automate lower level intellectual skill, allowing their users to concentrate on higher level thinking."[86]

A fourth model involves higher order thinking:

- *Collaborative thinking.* Collaborative tools enable teams of students to participate in creating, editing, and revising documents collectively, thus enhancing the possibilities for group wisdom. As they create and collaborate, students find their voices as they are recognized collectively and individually.

Another view of new models of learning compares the Traditional Classroom with the Classroom of the Read/Write Web.[87]

Traditional Classroom	Classroom of the Read/Write Web
Textbook	Staggering breadth and depth of content. Open-source type classrooms in which everyone contributes to the curriculum.
School teachers	Knowledge of primary sources such as authors, historians, and researchers.
Do your own work	Produce work in collaborative ways for larger audiences.
Lecture	Conversation.
Textbooks and more "closed" sources of information	Create own texts from different content providers such as blogs, wikis, websites, discussion groups, and so on. Teachers and students employ the many ways to find information on the web.
Reading as passive and "trusted" process	Active engagement in reading for truth and accuracy.
Paper-based content	Electronic learner portfolios.
Text-based writing	Write in many different genres.
Mastery of content as measured by passing a test	Electronic online portfolios.
Handing in assignments	Contribute ideas and work to larger body of knowledge that is the web.

Barriers and Challenges to Ubiquitous Technology for Learning

Evaluations of 1 to 1 programs point to the importance of ensuring that the systems are in place to support teachers as they use ubiquitous computing in the classroom. This starts with a clear focus on desired goals. Careful attention is required for planning, professional development, hardware and software acquisition, managing change, and program monitoring and evaluation.[88]

As ubiquitous computing expands to ubiquitous technology, with greater use of handheld mobile devices and Web 2.0 tools to support 21st century learning, other important issues arise. Some of these issues relate to the privacy of personal information, safety, and control. "The more invisible the technology, the harder it becomes to know what is controlling what, what is connected to what, where information is flowing, how it is being used, what is broken."[89] These are significant issues for educators and, in many ways, justify their reluctance to use these new and disruptive tools.

What's Next?

Alan Kay has predicted that "similar to the impact of printing, computers would only make a difference in people's lives if they were to become universally available," which he equated with affordable and portable.[90] With the growing access to multiple computers and digital devices for an individual anytime, anywhere, it appears that vision is just coming to fruition.

But policy makers should begin to build public vision and add capacity for technology-enabled ubiquitous learning now. They will benefit from the successes, setbacks, and lessons learned from 1 to 1 learning environments. Most importantly, educators need to recognize that with ubiquitous technology, the world becomes the classroom.

Research Findings Related to Ubiquitous Technology

While there are no national standards yet for measuring the success of 1 to 1 programs, results from individual schools and districts indicate the programs boost students' academic performance and test scores. This has been documented in the state of Maine, previously mentioned, and in other schools, including Pleasanton High School in Texas (see the next section).

The Pleasanton High School example speaks to one of the critical goals—and successes—of 1 to 1 programs: to close the digital divide and equip all students with the skills they need to succeed in the 21st century workplace. This is especially important for lower income students who may not have access to computers and the Internet at home. By helping to improve students' academic, creative, and technical skills, 1 to 1 programs support the needs and interests of local businesses and can help fuel local economic growth and development.

While most 1 to 1 learning programs focus on improving academic achievement, equity, economic development, and teaching, outcomes often extend far beyond those areas. One compelling outcome is the role students often play in teaching teachers how to use technology.

In a number of 1 to 1 programs, students play an important role in providing the first line of technical support. In Maine, for example, student "iTeams" help troubleshoot routine problems. In other programs, students play a similar role in providing technical support—both formally and informally—as part of the program design.

The results can be powerful, as noted by a teacher in the Maine Learning Technology Initiative: "We have a kid who isn't a top student. He doesn't get all A's, but he knows a lot about computers. The other teacher on my team is not very good with technology, and she goes to him and he loves that. It's been a way for him to stand out and make a difference."[91]

In addition, research shows that 1 to 1 programs have a significant impact beyond schools to families and communities, with students acting as mentors to parents, siblings, and other community members. The programs similarly energize parents, with marked improvements in parent-teacher interaction and parent attendance at school events.[92] Moreover, 1 to 1 programs increase teacher retention and enthusiasm as well as recruitment efforts.[93]

Pleasanton High School
Pleasanton Independent School District
Atascosa County, Texas

Located about 40 miles south of San Antonio, Texas, the rural Pleasanton Independent School District (PISD) spans some 440 square miles and eight communities. About 68 percent of PISD students receive free or reduced-price lunches. Many don't have Internet access at home. But through a 1 to 1 program launched in the 2001–2002 school year, all of the 1000 Pleasanton High School students—and all of their teachers—have a wireless notebook. The school's wireless network reaches all corners of the school grounds—even the parking lot.

Even more important than its physical reach, the 1 to 1 program is reaching students.

"We just feel that computers will prepare our kids for the 21st century skills that they're going to need," said PISD Superintendent Alton Fields. "Some of these kids would never have access to this type of technology if they didn't get it in the schoolhouse."

And the benefits of this access show, with the PISD staff reporting positive results. In a comparison of attendance rates, attendance was up a full 2 percent over the same period of the previous school year. In addition, student engagement has been extremely strong: Not a single discipline referral was reported for any of the 1000 high school students the day the notebooks were distributed, and enthusiasm for technology-based learning remains extremely high.

On the verge of becoming low performing just a few years ago, PISD is now regarded as exemplary. For example, on language arts standardized tests, the school's ninth graders scored 9.5 percent higher in the school year 2002–2003 than the average for all ninth graders in high schools in the same region; the school's tenth graders scored 16.5 percent higher; and eleventh graders scored 8.1 percent higher.

Results on standardized math tests were even better. For example, ninth graders scored 17.3, 33.3, and 38.4 percent higher on standardized math tests than other ninth graders in the region in 2002–2003, 2003–2004, and 2004–2005 respectively. Tenth and eleventh graders also scored well on these tests compared to other students in their grade levels during these school years.

School district test score data collected by Apple in 2006

Endnotes

[1] Editorial Projects in Education (EPE) Research Center. Diplomas Count: Ready for What? Preparing Students for College, Careers and Life after High School. *Education Week,* June 2007. http://www.edweek.org/ew/toc/2007/06/12/index.html

[2] SilentEpidemic.org. Ending the Silent Epidemic, 2007. http://www.silentepidemic.org

[3] Ibid.

[4] Uhalde, Ray & Strohl, Jeff. *America in the Global Economy: A Background Paper for the New Commission on the Skills of the American Workforce.* National Center on Education and the Economy, December, 2006. http://skillscommission.org/pdf/Staff%20Papers/America_Global_Economy.pdf

[5] Yankelovich, Daniel (November 25, 2005). Ferment and Change: Higher Education in 2015. *The Chronicle of Higher Education.* http://chronicle.com/weekly/v52/i14/14b00601.htm

[6] Partnership for 21st Century Skills (August 2, 2007). *Framework for 21st Century Learning*. http://www.21stcenturyskills.org/index.php?option=com_content&task=view&id=254&Itemid=120

[7] Jenkins, H. et al. (2006). *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century*. The John D. and Catherine T. MacArthur Foundation. http://www.digitallearning.macfound.org/site/c.enJLKQNlFiG/b.2108773/apps/nl/content2.asp?content_id={CD911571-0240-4714-A93B-1D0C07C7B6C1}&notoc=1

[8] Walker, Chip & Medeiros, Gia (March 30, 2006). GenWorld: The New Generation of Global Youth. BBDO Energy. http://www.energybbdo.com/uploads/GenWorld%20Overview.pdf

[9] *America's Digital Schools 2006, A Five-Year Forecast. Mobilizing the Curriculum.* The Greaves Group, The Hayes Connection, 2006. http://www.ads2006.org/main/pdf/ADS2006KF.pdf

[10] Casner-Lotto, J. & Brenner, M.W. (2006). *Are they really ready to work? Employers' perspectives on the basic knowledge and applied skills of new entrants to the 21st century U.S. workforce,* 50-51.

[11] Ibid.

[12] Sawyer, R.K. (2006). Introduction: The new science of learning. In R.K. Sawyer, *The Cambridge Handbook of the Learning Sciences* (19-34). New York: Cambridge University Press.

[13] Bransford, J.D., Brown, A.L., & Cocking, R.R. (1999). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

[14] Partnership for 21st Century Skills (August 2, 2007).

[15] Bransford, J.D., Brown, A.L., & Cocking, R.R. (1999).

[16] Casner-Lotto, J., & Benner, M.W. (2006).

[17] The Boyer Commission on Educating Undergraduates in the Research University (1998). *Reinventing undergraduate education: A blueprint for America's research universities,* 11. Accessed on Jan. 23, 2008 http://naples.cc.sunysb.edu/Pres/boyer.nsf/

[18] Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences, 3*, 265-283. Goldman, S.R., Duschl, R.A., Ellenbogen, K., William, S.M., & Tzou, C. (2002). Science inquiry in a digital age: Possibilities for making thinking visible. In H. van Oostendorp (Ed.), *Cognition in a Digital Age.* Mahwah, NJ: Erlbaum. Sandoval, W.A., & Millwood, K.A. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction,* 23(1), 23-55.

[19] Bransford, J., Barron, B., Pea, R., Meltzoff, A., Kuhl, P., Bell, P., Stevens, R., Schwartz, D., Vye, N., Reeves, B., Roschelle, J., & Sabelli, N.H. (2006). Foundations and opportunities for an interdisciplinary science of learning. In R.K. Sawyer, *The Cambridge Handbook of the Learning Sciences* (pp. 19-34). New York: Cambridge University Press.

[20] Casner-Lotto, J. & Benner, M.W. (2006). Secretary's Commission on Achieving Necessary Skills (SCANS) (1999). Skills and tasks for jobs: A SCANS report for America 2000. Washington, DC: U.S. Department of Labor. Downloaded from http://wdr.doleta.gov/opr/fulltext/document.cfm?docn=6140 on November 29, 2007.

[21] Doll, R. C. (1995). *Curriculum improvement: Decision making and process.* Boston: Allyn and Bacon.

[22] Ibid.

[23] Twenge, Jean (2006). *Generation me: Why today's young Americans are more confident, assertive, entitled—And more miserable than ever before.* New York: Free Press.

[24] Marzano, R. J. Pickering, D.J., Pollock, J.E. (2001). *Classroom instruction that works: Research-based strategies for increasing student achievement.* Alexandria, VA: ASCD.

[25] Johnson, D.W., Johnson, R.T. & Stanne, M.B. (2000). *Cooperative Learning Methods: A Meta-Analysis.* University of Minnesota. http://www.co-operation.org/pages/cl-methods.html

[26] Scardamalia, M. & Bereiter, C. (1992a). An architecture for collaborative knowledge building. In E. De Corte, M. Linn, H. Mandl, & L. Verschaffel (Eds.). *Computer-based learning environments* and problem-solving (pp. 41-66). Berlin: Springer-Verlag.

[27] iEarn Learning Circles site: http://www.iearn.org/circles/

[28] Johnson, D.W., Johnson, R.T. & Stanne, M.B. (2000).

[29] Newmann, F.M., Secada, W.G., & Wehlage, G.G. (1995). *A guide to authentic instruction and assessment: Vision, standards, and scoring.* Madison, WI: Center on Organization and Restructuring of Schools.

[30] Entwistle, N. (2000). *Promoting deep learning through teaching and assessment: Conceptual frameworks and educational contexts.* ESRC Teaching and Learning Programme, Conference 2000, Leicester, England.

[31] Newmann, F.M., Marks, H., Louis, K., Kruse, S., & Gamoran, A. (1996). *Authentic achievement: Restructuring schools for intellectual quality.* San Francisco, CA: Jossey-Bass Publishers.

[32] Newmann, F.M., Bryk, A. S., & Nagaoka, J.K. (2001). *Authentic intellectual work and standardized tests: Conflict or coexistence? Improving Chicago's schools.* Chicago, IL: Consortium on Chicago School Research.

[33] Berson, M. (1996). Effectiveness of computer technology in the social studies: A review of the literature. *Journal of Research on Computing in Education, 28* (4), 486-98.

[34] Kerski, J.J. (2003). The implementation and effectiveness of geographic information systems technology and methods in secondary education. *Journal of Geography, 102*(3), 128–137.

[35] Marcum-Dietrich, N. & Ford, D. (2002). The place for the computer is in the laboratory: An investigation of the effect of computer probeware on student learning. *Journal of Computers in Mathematics and Science Teaching, 21*(4), 361-379.

[36] Strickland, J. (2005). Using webquests to teach content: Comparing instructional strategies. *Contemporary Issues in Technology and Teacher Education, 5*(2), 138-148.

[37] Wenglinsky, H. (February 13, 2002). How schools matter: The link between teacher classroom practices and student academic performance. Education Policy Analysis Archives, 10(12). Retrieved Jan 24, 2008 from http://epaa.asu.edu/epaa/v10n12/.

[38] Kanowith-Klein, S., Stave, M., Stevens, R., & Casillas, A. (2001). Problem-solving skills among pre-college students in clinical immunology and microbiology: Classifying strategies with a rubric and artificial neural network technology. *Microbiology Education, 2*(1), 25-33.

[39] Pellegrino, J.W., Hickey, D.T., Heath, A., Rewey, K., Vye, N.J., & the CGTV (1991). *Assessing the outcomes of an innovative instructional program: The 1990-91 implementation of the "Adventures of Jasper Woodbury"* (Tech. Rep. No. 91-1). Nashville, TN: Vanderbilt University: Learning Technology Center.

[40] Scherer, M. (2008). Informative assessment. *Perspectives.* (December 2007/January 2008). Association for Supervision and Curriculum Development. p. 7. Accessed on Jan. 23, 2008 http://www.ascd.org/portal/site/ascd/menuitem.a4dbd0f2c4f9b94cdeb3ffdb62108a0c/;jsessionid=Hd1PGb4bJPAoUFnBoXhuX8xHfUnO9bSNbSZT2Q3jkY5CFjEU4EJL!1126004980

[41] Wiliam, D. (December 2007/January 2008). Changing classroom practice. *Association for Supervision and Curriculum Development,* 36-41.

[42] Bransford, J.D., et al. *How people learn,* 140-144. Stiggins, R.J. (2001). *Student-involved classroom assessment.* Upper Saddle River, NJ: Merrill Prentice Hall.

[43] Reeves, D.B. (2004). *Accountability for learning: How teachers and school leaders can take charge.* Association for Supervision and Curriculum Development, 160. Accessed Jan. 28, 2008 from http://shop.ascd.org/productdisplay.cfm?productid=104004E4

[44] Pea, R.D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *Scaffolding: A Special Issue of the Journal of the Learning Sciences.*

[45] Hakkarainen, K., Palonen, T., Paavola, S., & Lehtinen, E. (2002). *Networked expertise: Professional and educational perspectives.* Amsterdam, The Netherlands: Elsevier. Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development*, 49 (4),193-224.

[46] Barsh, J., Capozzi, M., & Davidson, J. (February 2008). Leadership and innovation. *The McKinsey Quarterly.* http://www.mckinseyquarterly.com/Strategy/Innovation/Leadership_and_innovation_2089

[47] Sutton, R. I. (September 2001). The weird rules of creativity. *Harvard Business Review,* 79(9), 96-103.

[48] Drucker, P. (2002). The discipline of innovation. *Harvard Business Review,* August 2002.

[49] Mendonica, L., Sutton, R. (January 2008). Succeeding at open-source innovation: an interview with Mozilla's Mitchell Baker. *The McKinsey Quarterly.* http://www.mckinseyquarterly.com/Strategy/Innovation/Succeeding_at_open-source_innovation__An_interview_with_Mozillas_Mitchell_Baker_2098

[50] Amabile, T. (1996). *Creativity in context.* Boulder, CO: Westview Press.

[51] Paulus, P.B. & Nijstad, B.A. (2003). *Group creativity: Innovation through collaboration.* USA: Oxford University Press.

[52] Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective, 193-224.

[53] Wentzel, K.R. (1991) as quoted in A. Wigfield, J. Ecoles, & D. Rodriquez (1998). The development of children's motivation in school contexts. *Review of Research in Education,* 23, 73-118.

[54] Finn, J.D. (1993). *School engagement and students at risk.* Washington, D.C.: National Center for Educational Statistics; and Steinberg, L. (1996). *Beyond the classroom: Why school reform has failed and what parents need to do.* New York: Simon and Schuster.

[55] Fredricks, J., Blumenfeld, P., & Paris, A. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59-109.

[56] Baumeister, R.F. & Leary, M.R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental motivation. *Psychological Bulletin, 117,* 497-529, as cited in Fredricks, J. et al. (2004).

[57] Wigfield, A., Eccles, J., & Rodriguez, D. (1998). The development of children's motivation in school contexts. *Review of Research in Education, 23,* 73-118.

[58] Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press. McCaslin, M., & Good, T.L. (1996). The informal curriculum. In D.C. Berliner & R.C. Calfee (Eds.), *Handbook of educational psychology* (622-670). New York: Macmillan.

[59] Guthrie, J.T., Van Meter, P., McCann, A., Wigfield, A., Bennett, L., Poundstone, C., Rice, M. E., Faibisch, F., Hunt, B., & Mitchell, A. (1996). Growth in literacy engagement: Changes in motivations and strategies during Concept-Oriented Reading Instruction. *Reading Research Quarterly, 31,* 306-325; as cited in A. Wigfield, et al. (1998).

[60] High Tech High. Charter school in San Diego California. Retrieved from http://www.hightechhigh.org/about/design-principles.php on December 24, 2007.

[61] Kozulin, A. (2003). *Vygotsky's educational theory in cultural context.* Cambridge University Press.

[62] Viadero, D. (2007). Social-skills programs found to yield gains in academic subjects. *Education Week, 27*(16), 1,15. Accessed on 1/22/08 from http://www.edweek.org/ew/articles/2007/12/19/16social.h27.html?print=1

[63] Zins, J.E., Weissberg, R., Wang, M., & Walberg, H. (2004). *Building academic success on social and emotional learning: What does the research say?* 3-5. New York: Teachers College Press.

[64] Fredricks, J., Blumenfeld, P., & Paris, A. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59-109.

[65] Hardy, L. (2007). Children at risk: Graduation Day. *American School Board Journal, 194*(9). Collaborative for Social and Emotional Learning (CASEL). Website accessed on Jan. 22, 2008 http://www.casel.org/

[66] Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective, 193-224.

[67] ISTE, P21, SETDA (2007). *Maximizing the Impact: The Pivotal Role of Technology in a 21st Century Education System,* 2.

[68] Ibid. 64.

[69] Madden, M. & Fox, S. (2007). Riding the waves of "Web 2.0." *Backgrounder, Pew Internet and American Life Project, 23,* 1. Retrieved December 1, 2007 from http://www.pewinternet.org/pdfs/PIP_Web_2.0.pdf

[70] Ibid. 13.

[71] Ibid. 2.

[72] Ibid. 4.

[73] National Center for Technology Innovation (NCTI) (2007). *Using the power of social media to promote assistive and learning technology,* 6.

[74] Greaves, T. & Hayes, J. R. (2006). *America's digital schools 2006: A five-year forecast.* The Hayes Connection and The Greaves Group, 15. Retrieved December 1, 2007 from http://www.ads2006.org/main/index.php

[75] Wilson, L.A. & Peterson, E.L. (2006). Measuring the value of one-to-one computing: A case study perspective. *One-to-One Computing, CoSN Compendium 2006.* Retrieved December 1, 2007 from https://my.cosn.org/mycosn/store/?storecat=2006%20Compendium

[76] Spellings, Margaret (2006). Speech delivered in Mountain View, CA on December 12, 2006.

[77] Zucker, Andrew A., Ed.D. (Draft: April 27, 2006). *1:1 (One-to-One) Computing: A Briefing for the Indiana Educational Technology Council.* http://www.indiana-etc.org/pdfs%5C1-to-1-computing.pdf

[78] Silvermail, D.L., Gritter, A.K. (2007). *Maine's Middle School Laptop Program: Creating Better Writers.* Maine Education Policy Research, University of Southern Maine. http://www.usm.maine.edu/cepare/Impact_on_Student_Writing_Brief.pdf

[79] Grunwald Associates, LLC, in cooperation with the National School Board Association. *Creating & connecting: Research and guidelines on online social and educational networking.*

[80] Richardson, W. (2006). *Blogs, Wikis, Podcasts, and Other Powerful Web Tools for Classrooms: Transforming teaching.* Thousand Oaks, CA: Sage Publications.

[81] Lyman, P. & Varian, H.R. (2003). *How much information 2003?* (Research Study-Executive Summary). University of California Berkeley, School of Information Management and Systems. Retrieved December 1, 2007 from http://www.sims.berkeley.edu/how-much-info-2003

[82] Richardson, W. (2006). 126.

[83] As quoted in Swan, K., Hooft, M., Kratcoski, A., & Schenker, J. (2007). Ubiquitous computing and changing pedagogical possibilities: Representations, conceptualizations and uses of knowledge. *Journal of Educational Computing Research,* 36(4), 481-515.

[84] Ibid. 481.

[85] Ibid. 482.

[86] Ibid. 482.

[87] Richardson, W. (2006).

[88] Bonifaz, A., & Zucker, A. (2004). *Lessons learned about providing laptops for all students.* Newton, MA: Northeast and the Islands Regional Technology in Education Consortium, Education Development Center, Inc.

[89] Ley, D. Ubiquitous computing, 76.

[90] Swan, et al. Ubiquitous computing and changing pedagogical possibilities, 483.

[91] Fairman, J. (2004). *Trading Roles: Teachers and students learn with technology.* Orono, ME: Maine Education Policy Research Institute, University of Maine Office. http://www.usm.maine.edu/cepare/pdf/mlti/MLTI%20Phase%20One%20Evaluation%20Report%203.pdf

[92] Lemke, C. & Martin, C. (March 2004). *One-to-One Computing in Maine: A STATE PROFILE.* Culver City, CA: Metiri Group. Lemke, C. & Martin, C. (April 7, 2004). *One-to-One Computing in Michigan A STATE PROFILE.* http://www.metiri.com/NSF-Study/MIProfile.pdf#search=%22A%20STATE%20PROFILE%20One-to-One%20Computing%20Michigan%22. Lemke, C. & Martin, C. (May 12, 2004). *One-to-One Computing in Virginia A STATE PROFILE.* http://www.metiri.com/NSF-Study/VAProfile.pdf#search=%22A%20STATE%20PROFILE%20One-to-One%20Computing%20Virginia%22

[93] Ibid.