Technology in Schools:

What the Research Says

A 2009 Update

CISCO

METIRI Group

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Back in 2006 Cisco commissioned Metiri Group to conduct a review of the research on the impact of educational technology on student learning. This first report, "Technology in Schools: What Does the Research Say?" was widely circulated and discussed among educators and education researchers.[1] Since then, a great deal of new research has been published on the impact of technology on student learning, prompting Cisco and Metiri Group to update the original report. However, it must be noted that research cited in this report is not intended to endorse a particular technology, intervention, model, test, method, strategy, or material.

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Technology in Schools: What the Research Says, was first published in 2006, and garnered significant success. This 2009 update represents a redesign to incorporate Web 2.0 participatory cultures of communication, collaboration, and interactivity and summaries of the latest research finds in educational technology.

Cisco is pleased to present to you this 2009 update. Readers are cautioned that this review is not intended to be exhaustive, but rather, to highlight major studies in the field.

INTRODUCTION

In this year of global economic crisis, policy leaders around the world are recognizing the critical importance of education to economic competitiveness and to the high quality of life for citizens. School leaders must think strategically about which technologies, tools, and programs will have the greatest impact on preparing students for the 21st Century.

Today's schools cite a myriad of purposes for technology in schools, including improved teaching, leadership, and decision making, as well as the following student-focused purposes:

- Increasing student engagement in learning
- Improving learning (e.g., higher standardized test scores)
- Improving the economic viability of students (e.g., increasing students' abilities to succeed in a 21st century work environment through collaboration, technology fluency, and high productivity)
- Increasing relevance and real-world application of academics
- Closing the digital divide by increasing technology literacy in all students
- Building 21st Century Skills (e.g., Learning & Innovation Skills, Life & Career Skills, Digital Literacy Skills, and interdisciplinary themes)[2]

Technology in schools: A look back

As the rate of penetration of the Internet rapidly increases in countries across the globe, and the investment in technological infrastructure in schools, teacher training, and software reaches into the billions, many are questioning its value.

The reality is that advocates have over-promised the ability of education to extract a learning return on technology investments in schools. The research studies now suggest that the error was not in citing the potential of technology to augment learning — for research now indicates that the effective use of technology can result in higher levels of learning. *The error was in underestimating the critical need for the system changes required to use technologies effectively in learning*.

This review of the past decade suggests five miscalculations on the part of educators:

- First, in being overly confident that they could easily accomplish the depth of school change required to realize the potential technology holds for learning—not an easy task
- Second, in their lack of effort in documenting the effect on student learning, teacher practices, and system efficiencies
- Third, in underestimating the time it would take to reach a sufficiency point for technology access
- Fourth, in not tapping into the participatory culture of Web 2.0 (e.g., engage students in collaborative, authentic work with outside persons globally and locally
- Fifth in underestimating the rate of change in technology, and the impact of such rapid, continuous change on staff time, budgeting, professional development, software upgrades, and curricular and lesson redesign

As a result, the real potential of technology for improving learning remains largely untapped in schools today.

The need for rethinking education is exacerbated by the advent of what is referred to as "Web 2.0" technologies, Web environments where participants both access and create content; such as Wiki's, Weblogs (Blogs), microblogs (Twitter), social networking environments (Facebook, MySpace, etc.) and virtual worlds (Second Life, etc); much is being written proclaiming these environments to hold tremendous potential as tools for teaching and learning. In a 2008 article, Rosen and Nelson describe a generation of students "who are comfortable with and enthusiastic about using collaborative technologies to participate in the World Wide Web as creators rather than consumers. These students gravitate toward group activity, seeking interaction within thriving online communities of generative individuals."[3]

The real potential of technology for improving learning remains largely untapped in schools today.

According to a recent national survey of school administrators completed for the MacArthur Foundation by CoSN and Metiri Group, districts across the country are wary of venturing into the world of social networking during school hours.[4] Recent news stories reporting cyber bullying and online predators give any responsible educator pause about turning students loose in these environments during the school day. However, as adults experience the positive aspects of social networking sites and as new, more secure social networking sites are developed, many anticipate recognition of the potential value of these sites.

While there is little current research related to the use of social networking tools, the promise of these tools might be supported by the literature related to a technology developed over 20 years ago. In the early to mid 1980's, Marlene Scardamalia and colleagues at the University of Toronto developed CSILE, Computer Supported Intentional Learning Environments. CSILE is a networked environment

that focused on collaborative “knowledge building.” Students in the CSILE environment both document and refine their own knowledge, and collaboratively.

More recently, a 3-year ethnographic study by a team of researchers led by Muzuko Ito was conducted for the John D. and Catherine T. MacArthur Foundation. They classified social networking into friendship driven – typically used to extend off-line friendships; and interest driven – those initiated by common interests of the group, or personal interests. They described the levels of use as “hanging out” (typically friendship driven), “messing around” and “geeking out” (typically interest-driven). Their paper suggests that the interest-driven online activity provides opportunities for youth to find peers that share their areas of specialized or niche interest areas. Through these networks, these youth gain opportunities to publish and distribute their work, access expertise, share their own expertise resulting in new forms of visibility and reputation.[5]

Researchers find that extracting the full learning return from a technology investment requires much more than the mere introduction of technology with software and web resources aligned with the curriculum. It requires the triangulation of content, sound principles of learning, and high-quality teaching—all of which must be aligned with assessment and accountability.

From speculation to scientific research

Reports from the British Educational Communications and Technology Agency (BECTA) in 2001 found that, “The historic research [related to Information and Communications Technology (ICT) in schools] is often on small samples, rarely controls out the effects of things other than ICT, and is rarely rigorous enough in its methodology or its search for explanations of findings to support the weight that has been put on it.” The report goes on to say that research in the agency’s recent publications “sets new standards of methodological decency in this area of research.”[6] In the U.S., the level of attention in educational research has also increased, in large part because of the rigorous research standard established by the Institute of Education Sciences (IES).

Further research on the use of technology in informal learning suggests that educators must find a way to recast learning to include the informal learning of children and youth beyond the school day.[7]

A look at research

Educators often use best practices, i.e., those widely adopted by experienced, respected educators, to inform their instructional decisions. In fact, as new theories, techniques, and strategies for learning are introduced and tested, the field depends on expert review and commentary to identify innovations that seem to be working. This phase of the scientific process is important in that it determines which innovations merit further, more rigorous study—and it shapes the research questions or hypotheses about such innovations. However, far too many educators discuss research and best practices without distinguishing between them. For the purposes of this paper, the two primary categories of research design used to classify the studies include (1) experimental or quasi-experimental studies (including meta-analyses), and (2) descriptive or correlational studies.

For questions about relationships of cause and effect, experimental studies are considered the “gold standard.” Quasi-experimental studies are the next most valuable for establishing cause and effect, but since they involve fewer experimental controls and no random assignment there is less confidence in their results. Descriptive research describes processes, subjects, or relationships but does not identify causal connections. While experimental studies are able to provide evidence that a certain cause results in a certain effect, descriptive studies provide at least a tentative explanation of how or why that might happen. One type of descriptive research is the correlational study.

Correlational studies provide evidence of a correlation between two or more variables, but the presence of a correlation is no guarantee of a cause.[8] Table 1 provides the different types of research, the questions they address, and the corresponding research designs.

Table 1. Definitions of the Categories of Research Used as Evidence

Type of Research	Research Question	Research Design
Experimental	Does something cause an effect?	Experimental
		Quasi-Experimental
Descriptive	What is happening?	Simple Descriptive
	How is something happening?	Comparative Descriptive
	Why is something happening?	Correlational

Inclusion of studies

The review team chose which studies to include based on representativeness, relevancy, and overall quality and reputation of journal and/or authors, but cautions the reader that this selection process is inherently subjective. To the extent that the process works, it reflects the authors' knowledge of the discipline and critical issues. At the same time, bias (intentional or unintentional) is likely to impact the inclusion and exclusion of works that other reviewers may find relevant. A full description of the methodology used to locate the studies selected sites can be found in the Appendix.

Rating of studies

Each TECHtype (i.e., classification of technology or technology use) is rated based on the strength of evidence of effectiveness. As shown in Table 2, three rating symbols were used to summarize the overall findings of the studies. Reviewers condensed the findings from the research into evidence tables based on the type of research study and type of learning.

Table 2. Rating icons

Icon	Rating
+	Primarily promising effects
+ −	Mixed effects
−	Primarily negative effects

Research findings were examined and rated based on the following types of learning (see *Table 3*):

- Basic Skills
- Higher Level Thinking
- Information, Communication, & Technology (ICT)
- Collaboration/Participatory Learning
- Engagement In Learning

Table 3. Type of Learning

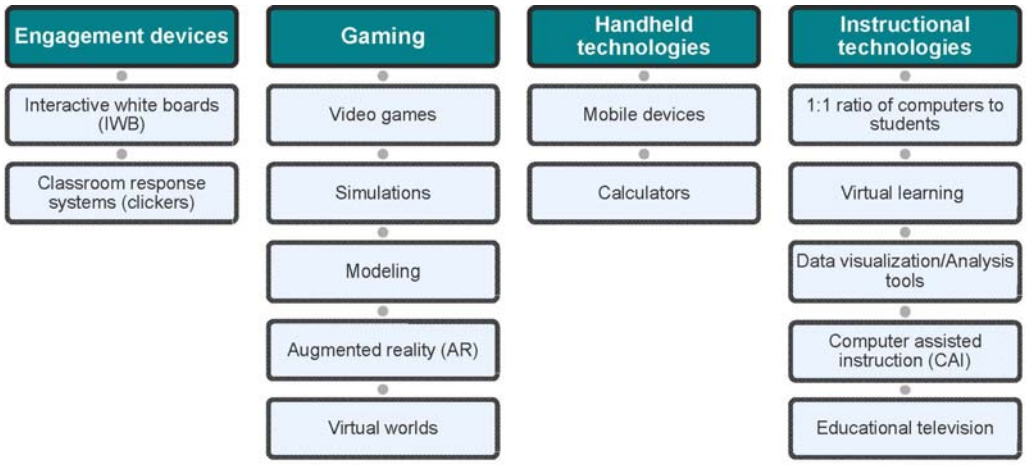
Type of Learning	Research Design
Basic Skills	Basic skills are those considered necessary to be functionally literate and numerate in today's society (reading, writing, arithmetic, etc)
Higher Level Thinking	Higher level thinking is the use of cognitive skills or strategies (e.g., deductive reasoning, hypothesis testing, argument analysis, creative thinking, critical thinking, etc.) to that increase the probability of a desirable outcome.
Information, Communication, & Technology (ICT)	ICT skills represent the students' ability to generate meaning through exchanges using a range of digital and online tools and processes.
Collaboration/ Participatory Learning	Collaboration and participatory learning represent the students' capacity to interact with others in ways that contribute to the collective accomplishments of the group.
Engagement in Learning	Engagement is defined here to mean deep involvement in learning on cognitive, social emotional, and behavioral levels.

Note: The categories of learning outcomes in this second issue differ somewhat from the first issue of the publications. The 2009 issue expanded upon the former to incorporate Web 2.0 participatory learning.

Organization of report

This report is organized to examine the research on 14 types or configurations of technologies (TECHtypes) used in education. As shown in Figure 1, each TECHtype was grouped under (1) Engagement devices, (2) Gaming, (3) Handheld technologies, or (4) Instructional technologies.

Figure 1. Organization of TECHTypes



Each section provides details about the specific TECHtype, including summaries of the rigor and outcomes of recent studies. The studies included in the report are not meant to be comprehensive, but rather indicative of the results possible when technology is coupled with appropriate pedagogy and implemented with fidelity. Definitions are provided throughout the report and can also be found in the Glossary.

INTERACTIVE WHITEBOARDS

An interactive whiteboard (IWB) is a presentation device that is connected to a computer, thus enabling users to display and manipulate computer images on a digital projector. Users can control the software from the computer or directly from the board, using a pen or highlighting tool to add notations or emphasize the intended object. The teacher or student can run the software directly from the board using his/her finger as a mouse. All activities performed on the board can be saved, printed out, and distributed to the whole class.[9]

IWBs are proliferating in classrooms around the world, becoming standard equipment in many schools. According to a March 2009 report from Futuresource Consulting, over 600,000 interactive whiteboard units were sold worldwide last year, 250,000 in the U.S. alone. Sales in the U.S. were up 65%, with strong sales in the UK and Australia as well, and projections estimate one in six classrooms will be hooked up with an interactive whiteboard by 2012.[10]

Its appeal lies in the opportunity for use of dynamic, interactive images, animations, video, and text of a size visible to an entire classroom. While many teachers, students, and school districts are enthusiastic about the use of interactive whiteboards, it remains unclear whether such enthusiasm is being translated into effective and purposeful practice.[11] Multiple studies identify a distinction between the use of IWBs as a tool to enhance teaching (e.g., flexibility, versatility, efficiencies, interactivity, saving work, etc.) and its use as a tool to support learning (motivation and affect, multimodal stimuli, etc.). In order to ensure that the IWBs are used as a tool to support learning, teachers must be properly equipped not only with the technical capability with IWBs but also with a clear understanding of interactivity, active learning strategies, scaffolding of student learning, and engagement facilitated in whole-class and small group instruction.

To date, the impact on academic achievement has been mixed. Some studies reported increases in achievement among students using the IWB compared to those not using them, while others reported no lasting gains.[12] A recent study in the U.S. (see Haystead and Marzano below) found that, under very specific conditions, significant gains could be achieved using IWB in comparison to classrooms without such IWB use. In contrast, a large-scale study UK study reported initially (after one year), very small, but positive differences in academic gain scores between comparison groups at Years 5-6, but, by the end of the second year, found that no significant differences could be detected. That same UK study found that the use of the IWB resulted in more whole group learning and less small group work for mathematics and literacy lessons.[13] The final report found that when IWB use in the UK was extended to secondary schools, initial increases in student motivation were short-lived, and researchers could detect no significant differences in academic performances of students.[14,15]

The literature suggests that while teachers may be teaching more creatively with interactive IWB resources, students will continue to play a passive role if teachers do not engage them in active higher order thinking processes through student-centered uses of these devices. A review of the literature found studies that noted the use of the IWB facilitated an increased pace to lessons and increased student motivation, but the jury is still out as to whether or not this technology will result in increased learning. The mixed reviews suggest that more nuanced studies are needed to distinguish types of use, intended outcomes, complexities of learning, content foci, and audiences.[15,16]

SUMMARIES OF RESEARCH STUDIES ON INTERACTIVE WHITEBOARDS (IWB)*

*Not intended to be comprehensive.

- **Haystead and Marzano.** The study examined whether IWBs had an impact at different grade levels and across academic content areas in schools around the U.S. The study involved over 3,000 students split into a control and treatment group. The researchers conducted 85 studies with 79 teachers from 50 schools, treating each as independent, using non-equivalent, pretest/posttest quasi-experimental study design. The researchers excluded data from students with negative gains. They reported 21 studies with negative, no, or low effects, 42 with medium effects, and 22 with large effects. Their analysis was K-12, with positive overall effects in elementary and high school, but with overall low effects at middle school grades (specially no effects at grade 7). Meta-analytic analysis revealed that overall, the treatment group outperformed the control group by 17 percentile points. The study reported relatively large percentile gains in student achievement did occur, but only under the following conditions: a teacher has 10 years or more of teaching experience; has used the technology for two years or more; uses the technology between 75 and 80% of the time in his or her classroom; and has high confidence in his or her ability to use the technology.[17]

- **Year 5-6 Use of IWBs (UK)**. A large-scale, longitudinal study in the United Kingdom studied the use of IWBs in Year 5 and 6 classes in over 70 elementary schools performing above the national average. The study found an overwhelmingly positive response from teachers and students. Over the two-year period of the study, teachers moved toward increased classroom interactivity and effective questioning strategies, albeit moving away from small group interactions and toward more whole class instruction. By the end of Stage 2: a) in mathematics, the IWBs benefited high performing students, but had little effect (although not a detrimental effect) on low-attaining students. In science, all students (especially low performing boys), with the exception of high-attaining girls were benefited. The results on English and writing were inconclusive, with some gains noted for low attaining boys. The study also reported increases in student engagement and motivation across the two years and an increase in the pace of the lessons.[14]

- **Native American students**. A 2004 study looked at the effects of using interactive whiteboards to teach geometry to Native American elementary students. Gain scores from students whose teachers used IWBs were compared to gain scores from students whose teachers did not. The authors found statistically significant gains for students taught using interactive whiteboards, with the interactive whiteboard group averaging a mean gain score of 20.76 points and the control group averaging a mean gain score of 11.48 points.[18]

Table 4. Research in Learning through Interactive Whiteboards (IWB)

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+ –		+	+ Whole group – Small group	+
Correlational or Descriptive/Correlational	+	+	+	+ Whole group	+

NOTE: "+" indicates primarily promising findings;"+ –" indicates mixed findings; and "–" indicates primarily negative findings.

CLASSROOM RESPONSE SYSTEMS (“CLICKERS”)

Classroom Response Systems, Audience Response Systems or, more commonly, “clickers,” are devices, normally deployed with one per student, which allow teachers to pose questions and electronically collect responses from individual students.

Clickers are in use from the primary grades through post-secondary education. There are now multiple vendors providing the technology, which is becoming increasingly more sophisticated and interactive each year. While the most basic use of clickers may seem to be fairly low-level and factual, they are increasingly being linked with higher-order, inquiry-based learning. The body of research and theory underlying the use of clickers in the classroom falls into the following four classes:

- Teaching and learning practices
- Teacher efficacy
- Student achievement
- Student engagement

While much of the most compelling research is at the post-secondary level, there is a small but growing literature base extending down into K-12.

Teaching and learning practices

This branch of research and theory looks, not at the impact of clickers on students or teachers, but at the kinds of teaching and learning practices that clickers can support. In a recent study of the use of clickers in the K-12 environment, Penuel et al. looked at the use patterns of 498 elementary and secondary educators.[19] Among the findings of this study was that K-12 educators tended to use clickers in ways that were similar to post-secondary users. These uses included:

- Checking for student understanding of the content being taught in real time
- Diagnosing student misconceptions and misunderstanding
- Displaying the responses of the group to trigger discussion and reflection
- Gathering formative data to guide instruction
- Saving time in the administration and scoring of quizzes

Teacher efficacy

Also in the Penuel study, researchers defined four levels of use ranging from infrequent users who rarely used the clickers and used them for only one or two purposes to users who used the clickers frequently and for a variety of purposes. Teachers who were generally comfortable with technology were more likely to fall into the latter category, as were teachers who had received more professional development related to instructional strategies for clicker use. An interesting point made within this finding was that while the amount of training in instructional strategies using clickers was related to the frequency and variety of use, the amount of technical training in the use of clickers was not.

Student achievement

Most research studies that are currently available related to the use of clickers were conducted at the post-secondary level. As indicated below, one of the largest correlational studies undertaken at both the high school and university levels found the impact of clickers to be similar for both. Much more research is needed, however, as there appears to be significant evidence that it is not the clickers that makes the difference; it is the teaching and learning strategy that the clicker supports that is the key.

Student engagement

One of the most consistent, though primarily anecdotal, findings related to the use of clickers is their impact on student engagement. In the Penuel study, researchers established a strong linkage between positive student perceptions of their classroom environments and the frequency and quality of clicker use.

SUMMARIES OF RESEARCH STUDIES ON /CLASSROOM RESPONSE SYSTEMS ("CLICKERS")*

*Not intended to be comprehensive.

- **Physics students**. A correlational study of over 6,000 physics students, including high school physics students for whom results were disaggregated, demonstrated that the use of "interactive-engagement" strategies, many of which were those used with clickers, were associated with almost double the growth in physics learning when compared to more traditional, non-interactive classroom learning. When disaggregated, the high school results were similar to those for the study overall.[20]
- **A descriptive study.** In a major study of elementary and secondary school clicker use, the classrooms of teachers using these devices for a variety of purposes were associated with more positive classroom environments and higher levels of student engagement.[19]
- **Quasi-experimental study (Singapore).** In a small study with a quasi-experimental design in Singapore, high school physics students completed a three-week physics unit where they were pre- and post-tested on the content of the unit. While the two classrooms were equivalent in knowledge at the start of the study, the classroom using clickers performed significantly higher at post-test. The test was constructed as an equal mix of factual and open-ended questions and treatment (clicker) students outperformed control on both. While the short timeframe of the study and the small sample size limit the generalizability of the results, the effect size was quite large (0.85).[12]

Table 5. Research in Learning through /Classroom Response Systems ("Clickers")

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+			+	
Correlational or Descriptive/Correlational	+	+ −	+ −	+	+

NOTE: "+" indicates primarily promising findings;"+ −" indicates mixed findings; and "−" indicates primarily negative findings.

VIDEO GAMES

Video games are competitive, artificially constructed technology-based activities with a specified goal and a set of rules and constraints used within a specific context.[21]

Gaming is flourishing among teens and adults alike. According to a recent national study by Pew Internet and Family Life, 97% of adolescents between the ages of 12 and 17 play video games. These adolescents use a broad range of technology devices for game playing. While the largest percentage (86%) play on a console like the *Xbox, PlayStation*, or *Wii,* 48% say they play on portable gaming devices, such as Sony *PlayStation Portable*, *Nintendo DS*, or *Game Boy*, and 48% use a cell phone or handheld organizer.[22] The types of games played, in order of frequency of use by students as noted in the Pew study includes: racing, puzzle, sports, action, adventure, rhythm, strategy, simulation, fighting, first-person shooters, and role-playing. Gaming experts generally agree that the following six game attributes strongly support learning: fantasy, rules/goals, sensory stimuli, challenge, mystery, and control.

Despite this widespread use outside of classrooms, a review of the literature finds a dearth of causal research on the value of gaming to learning. What empirical studies are available typically involve a range of age groups including a very small numbers of K-12 students. The majority of that small number of K-12 studies do find somewhat positive effects in comparison to traditional learning in three areas: academic achievement, attitudes toward learning, and self-concept, with a minority of the studies reporting no impact. Motivation to learn is often touted as a reason to use games in education. In some cases the motivation is extraneous to the content. Examples include the well-known software, Math Blaster and Mineshaft, where the gaming provides the motivation for completing drill and practice exercises in mathematics, but is extraneous to the learning. Research suggests that this type of gaming, with instructional support, results in positive gains in cognitive skills in comparison to conventional instruction. Without instructional support they are not superior to other instructional approaches, and can be detrimental to learning.[21 23 24]

Other types of educational gaming engage the student in incremental stages of solving problems integral to the targeted learning (e.g., SimCity or Civilization). In those situations, achieving the learning outcome (e.g., running a viable city, keeping a civilization alive) is synonymous to winning the game. With respect to this latter type of game, our review has turned up many descriptive studies that address more nuanced questions related to the effect of particular gaming characteristics. The descriptive studies report that games often are used in schools to offer immediate feedback, increase active learner participation, reinforce knowledge, and influence attitudinal changes.[25]

Educators who use gaming with their students typically target the development of complex thinking skills and problem solving, planning, and self-regulated learning. The descriptive research in this area shows promising results, with most researchers commenting on the complexity of gaming, and the difficulty of distinguishing which attributes of the games were responsible for the outcomes in their studies. They also discuss the difficulty of using this type of educational game in schools due to the time restrictions of class periods, the need for continuous scaffolding to guide students' learning, and the need for more constructivist, inquiry instructional strategies that are often not familiar to teachers. The more rigorous studies are showing some promising results,[24] but have yet to identify clearly the specific attributes of games that contribute to such learning.[23]

A new body of work in serious gaming is now emerging, through the generous investment of the John D. and Catherine T. MacArthur Foundation in a series of digital media studies. That Foundation has published a series of papers on the Ecology of Games that is a must read for anyone interested in educational gaming. In the introduction to the series, Katie Salen states that "games already operate as robust learning systems," albeit unnoticed by the education community.[26] The series extends the concept of serious gaming to include the new literacies that gaming advances, including: a) learning to "read" a game, and thus understand a complex system; b) learning to navigate the complex out-of-game resources that surround the gaming culture; c) learning to negotiate the variable demands of fair play; and d) becoming literate in the social norms of a community.[26] The authors of this series take issue with the fact that schools have yet to see "games as learning systems," and suggest that gaming offers students opportunities to enter a system where they can do the following:[26,27,21,28,29\\]

- Set the timing and pace of learning
- Navigate landforms, maps, mazes, buildings, and other virtual sites
- Experience various perspectives
- Practice systems thinking and strategic planning
- Build and test models
- Engage in risk-taking
- Interact socially
- Interpret multi media
- Solve problems
- Ask questions
- Create meaning
- Negotiate
- Collaborate
- Make individual and group decisions
- Use data/evidence to inform decisions
- Write, compose, and produce
- Communicate
- Explore interests
- Express opinions and positions on issues

Many researchers, including those authoring the MacArthur series, suggest that the value of gaming to education will depend on a transformation of schools into systems that are more student-centered, adaptive to each students' needs and measured as to metrics related to 21st Century skills, beyond just academics. This new body of work calls for more nuanced studies that identify which gaming attribute contributes to which student outcomes.[30,26]

SUMMARIES OF RESEARCH STUDIES ON VIDEO GAMES*

*Not intended to be comprehensive.

- **Games and learning**. Researchers in a recent 2009 review of research on gaming in education found that "games can lead to better cognitive, skill-based, and affective outcomes." However, the researchers also commented that the studies reviewed did not isolate specific attributes of games that would reveal which attributes were largely responsible for the results, nor the degree to which the level of application of each attribute contributed to the student outcomes.[23]
- **Geography**. Researchers examined the effect of gaming on the learning of geography by fourth and fifth grade students. Results indicate that the students had significantly more positive learning gains when learning about world continents and countries through the Global Village game than with traditional studies of the those topics.[31]

- **Mathematics.** In 2008, researchers conducted a study on the impact of a mathematics game, DimensionM, on achievement and course motivation of students in high school algebra. Using a randomized controlled trial study design, the researchers reported that the students using DimensionM registered a statistically significant, positive gain in mathematics achievement.[32]

- **Meta-analysis.** In 2005, a review of the research on instructional gaming was conducted by a division of the U.S. government. That review found little evidence to support increased learner motivation beyond the gamers' motivation to continue playing the game. They noted that such motivation would only be beneficial if the games were designed to meet instructional goals (often the "gaming" in the learning activity serves to motivate, but the actual gaming action and "win" have little to do with the content). The reviewers did find evidence that people can learn through games, but cautioned that research does not show that games are always a better alternative to other instructional approaches. However, the authors also noted the limited amount of empirical evidence related to educational gaming.[21]

Table 6. Research in Learning through Video Games

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+	+ −		+	+
Correlational or Descriptive/Correlational	+		+	+	+

NOTE: "+" indicates primarily promising findings;"+ −" indicates mixed findings; and "−" indicates primarily negative findings.

SIMULATIONS

Simulations are interactive models that emulate real-world phenomenon through pre-defined rules of operation, behavior of objects, and interaction among the objects they encompass.

Researcher Margeret Gredler (2009) describes simulations as “experimental exercises that transport learners to another world.[33] There they apply their knowledge, skills, and strategies in the execution of their assigned roles.” Examples range from students serving as city planners laying out a cityscape, to students in the role of field scientists collecting and analyzing data on a simulated field trip, to students as biologists electronically dissecting a frog. An important element of the simulation is the challenge in solving an ill-defined, as opposed to a well-defined problem. A simulation is based on a foundation of dynamic relationships that reflect real-world phenomenon.

Simulations are typically used to produce a set of evolving case studies as students run the simulations with various datasets. There are two types of simulations: experiential and symbolic. The experiential (e.g., Civilization, Interactive2, etc.) provide the students with experiences where they interact as a participant, acting within the parameters and constraints of the game, receiving feedback, and continuing to make decisions as the situation evolves and consequences and benefits emerge. A symbolic simulation offers a different type of experience for the learners, one in which they serve as researchers, experimenters, or troubleshooters. The symbolic simulations, which unlike the experimental, are not classified as games, include Genetics Tool Kit, Frog Dissections, or Tidepools.[34] A hybrid of the two has also emerged where students have the advantage of playing a role within the simulation, along with the advantage of receiving scaffolding to promote reflection on the concepts behind the simulation.[33]

The advantages of classroom-based exploratory learning through experiments are well documented. For example, researchers conducted a comparative review in seven different countries with pre-university students of physics. They found that in those countries where student knowledge was developed through experimentation, students’ thinking abilities and understanding of physics were more developed than in students from countries lacking this component.[35]

The characteristics of simulations that contribute to learning include:

- An adequate model of the complex real-world situation with which the student interacts (referred to as fidelity or validity)
- A defined role for each participant, with responsibilities and constraints
- A data-rich environment that permits students to execute a range of strategies, from targeted to “shotgun” decision making
- Feedback for participant actions in the form of changes in the problem or situation[34]

Research results on the merits of computer-based simulations are mixed. Some researchers suggest that, without scaffolding (either by the teacher or through added features in the simulation), many students will run the simulations without fully understanding the underlying principles or concepts.[36] Researchers report that the hybrid simulation that includes features of both experiential and symbolic simulations had better results than the experiential simulations alone.[33]

Kurt Squires, a professor at the University of Wisconsin (Madison campus) published a paper that touts the merits of open-ended simulations. A key simulation discussed in the paper is *Civilization*, a

simulation game that engages students emotionally as it allows them to learn by manipulating complex variables. As "designed experiences," they capture the sense of environments that are worth understanding (e.g., emulate experiences that immerse them in situational learning). Moreover, they support multiple trajectories that provide students opportunities to play the games literally hundreds of times and have a different experience each time. As they do so, players gain knowledge about and experience with the simulated environment. For example, good players will develop systems thinking, recognizing how one factor (i.e., economics of a civilization) will impact other factors (i.e., politics, quality of life). The researcher also noted the difficulty of using game play as a learning strategy within the constraints of the traditional 45-minute class, which often doesn't allow students time to develop and explore specialized knowledge often acquired by users, nor to fully leverage the social systems that naturally accompany the gaming experience (e.g., away from the game, web and blog sites are established where users can discuss strategies, share modifications they have made to the simulation, etc.).[25]

SUMMARIES OF RESEARCH STUDIES ON SIMULATIONS*

*Not intended to be comprehensive.

- **Civilization.** Civilization is a complex, open-ended simulation that enables the student to explore history by immersing himself in the game. Due to the nature of simulation, no two games are alike. This enables the student to reflect on his experiences, and come to understand a system, experiment with multiple ways of being within that system, and then use the system for creative expression. This descriptive study calls these open-ended simulations "possibility spaces," where players can develop/try on new identities. The researchers asked students to read critiques of U.S. foreign policy related to imperialism across U.S. history prior to playing the game. Researchers commented on how surprised they were at the students' materialistic views of the world. They felt that the simulation provided students with opportunities to see the U.S. interests in the acquisition of foreign resources (e.g., oil, rubber, etc.) as colonization versus the rhetoric of "spreading democracy." There was no evidence that the students' ethical beliefs about war were altered due to the gaming experience. However, they did appreciate experiencing and "replaying" history without the ideology often included in historical texts, and gained understanding of geopolitical clout and national economic issues. The authors commented on the time required to engage students fully in this experience, and noted the need to scaffold interactions and facilitate debriefings to make underlying structures visible to students.

- **Science - Supercharged.** In 2008, researchers at the University of Wisconsin, Madison, developed a game called Supercharged that addressed the topic of electricity. It placed students in a maze through which they had to propel themselves by strategically placing electrical charges, in essence, allowing students to "think like a particle." The researchers reported mixed results, with students not used to participatory learning initially confused by the complexity of the simulation, and then not clear as to what the underlying reasons behind the simulations indicated. That said, the experimental group outperformed the treatment group on conceptual understanding, and in post interviews the students used game concepts to solve complex physics problems. [37,36]

- **Meta-analysis.** In a 2006 meta-analysis of 32 empirical studies, researchers found that the use of interactive simulations and games resulted in higher cognitive gains when compared to traditional instruction. Further analysis indicated that a key factor in such gains was student control; when the teacher or the computer dictated the sequence of the programs, no advantage was found.[24]

- **Case studies by FutureLab (UK).** The FutureLab conducted one-year case studies of teachers using electronic, off-the-shelf games (e.g., simulations) in formal education with students ages 11-16. They found that: students were motivated to learn with games when they had a degree of autonomy and when they used games that were familiar from home environments; the fixed length of lessons was a constraint in using the games; students were not as facile with the games as teachers expected; the effective use of games for learning depended more on teachers' effective use of existing instructional approaches than on the development of any new game-related strategies; and teachers were not sidelined, but instead, played a central role in supporting and scaffolding student learning through games.[38]

Table 7. Research in Learning through Simulations

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental		+ −		+	+ −
Correlational or Descriptive/Correlational	+	+	+	+	+

NOTE: "+" indicates primarily promising findings;"+ −" indicates mixed findings; and "−" indicates primarily negative findings.

MODELING

Models are interactive representations of real-world phenomenon, where users are able to manipulate the underlying structure (i.e., rules, objects, behavior of objects, and rules of operation) of the representation.[39, 40, 41]

Simulation and modeling are often used interchangeably in the literature. In this paper, we make a clear demarcation of the two based upon the nature of the activities that they can support. The demarcation between simulation and modeling is analogous to that between toy cars and Lego bricks–the difference between play and construction.[42] Simulations can be classified as models with pre-defined rules of operation and interaction among objects they encompass. Simulations can be used to support exploratory learning activities in which students can explore the simulation by manipulating the variables or parameters provided, but not the underlying theories and rules of operation. In contrast, modeling environments provide students with a greater flexibility to modify models or even construct their own models by creating objects and defining the rules of interaction. Modeling therefore extends the scope of learning from exploratory to encompass more expressive activities.[43,44]

Studies that contrasted the use of simulations to modeling, noted that while simulations are exploratory tools, models are experimental tools. With simulations students run an experiment or play a game repeatedly to explore patterns in the results. In modeling, the student is actually manipulating or recalibrating the underlying formulas (assumptions) of the model to modify outcomes.

Simulations do provide opportunities for exploration of concepts, however, often students become adept at “winning” the game or getting a desired outcome, but walk away without a clear understanding of the underlying concepts the simulation was intended to teach. In direct contrast, modeling has been found to create a dynamic tension between students’ conceptions and scientific explanations. Some researchers suggest that, while respecting students’ ideas, modeling provides opportunities for creating cognitive dissonance that can lead to the correction of misconceptions.[41] Other researchers suggest that rather than correcting misconceptions, teachers should use the exploratory modeling as opportunities to build on prior knowledge, regardless of how accurate it is.[45] This is particularly important in the sciences where people’s intuitive conceptions of the world around them are at odds with scientific explanations. The challenge to educators is how to use students’ current understandings of the world to build scientific understandings of that world. Researchers suggest that this can be accomplished by engaging students in the construction of personally meaningful models.[45, 46]

The literature indicates that modeling provides opportunities for students to:[45]

- Improve their understanding of the natural world
- Design their own representation of natural phenomenon
- Discuss elements of natural phenomenon unbiased by the complexity of the real-world
- Reflect on their own thinking

Since models are most often created electronically, using computer programs to develop, run, analyze, and refine models can be an important learning experience for students. In some cases the models are developed within spreadsheets, visualization tools, or through the programming in

computer languages. In other cases dynamic icon-based systems models such as STELLA, Model-IT, or My World may be used to build and run the model. In icon-based systems, symbols are used to represent processes and students are able to define the underlying formulas for each symbol. Often, the modification of games (modding) may serve as the vehicle for altering the underlying structure of a gaming system.

STELLA is an icon-based, dynamic systems model used in K-12 education. STELLA requires that students select types of objects and relationships to establish the elements of a dynamic system and then define the logical and arithmetic connections between them. This two-step process is important for students to emulate as it is representative of how experts tackle problems. STELLA then generates the formulas behind the scenes. STELLA is used to simulate a system over time, connect theory to the real world, enable students to change the underlying structure of a system and then observe the results. One of the drawbacks to STELLA is that it requires the student to understand stocks, flows, and connections, which itself may represent a steep learning curve for some students before they can begin to use STELLA to model systems. While case studies have been conducted on the use of STELLA in schools, with positive results, no experimental or quasi-experimental design studies have been conducted to date.

Students can also engage in modeling when they construct their own games, dynamic spreadsheets, or other computer-based systems that require inputs and display resultant outputs. For example, the Massachusetts Institute of Technology (MIT) has established a programming language called Scratch that enables students to build and run visual models with objects and routines. To date the research reports on Scratch have been descriptive, documenting a range of creative models generated by 9-10 year olds and a community that developed online around the work. Examples include weather reports, political analyses, geometry concepts, and environmental projects. The site supports a learning web that includes peer-to-peer learning, collaborative building, and skills exchange. Often students create objects that are then discussed and used by other students in their projects.

Another example is StarLogo based on Seymour Papert's Logo programming language. It has structures that enable students to explore real-world phenomenon where complex structures work, not through centralized rules, but through a set of simple heuristics/rules or behaviors that over time result in complex systems. Examples include: ant colonies, forest fires, traffic jams, and even waves at football games. Descriptive studies suggest that the microworlds established and explored by students and teachers served as what Papert calls "incubators of knowledge (p. 50)."[47]

Summaries of research studies on Modeling*

*Not intended to be comprehensive.

- **Genetics.** Genetics involves abstract concepts that students in grades 7-12 often find difficult to understand, since they are not observable. Typically science labs for genetics are confined to quantitative simulations. In a descriptive study using WorldMaker, high school students built an iconic model to test the rules governing the behavior of the genetics over generations. Researchers found that such modeling revealed their misconceptions and generated thinking that emulated the scientific view. They noted that it helped students to understand more deeply difficult concepts such as genotypes and phenotypes, and genetic ratio.[48]

- **Ecosystems.** This study compared the knowledge acquisition and transfer of fifth grade students studying ecosystems through modeling with Stagecast Creator in comparison to that of students using traditional worksheets. Using the software, students in the treatment group created, tested, debugged, and refined routines with complex rules that simulated the behaviors of marine species. Results indicated that the students using the modeling software not only outperformed the control group on six aspects of modeling, but, were also able to transfer their modeling skills and knowledge across domains. The six aspects of modeling were: formulating models; extracting information from a model; model revision through comparison and formulation of new ideas for improvements; comparison evaluation of models of same phenomenon; appreciation of the purpose and utility of models for learning; and reflecting on the process of model development and refinement.[49]

Table 8. Research in Learning through Modeling

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental		+	+		
Correlational or Descriptive/Correlational	+	+	+	+	+

NOTE: "+" indicates primarily promising findings;"+ –" indicates mixed findings; and "–" indicates primarily negative findings.

AUGMENTED REALITY (AR)

Augmented reality (AR) experiences involve individuals or teams interacting in the real world while simultaneously using images, text, visuals, and/or global satellite positioning that have been mapped to their real world situation.

Students involved in AR simulations use the real world as their game board. For example, students might become a security team trying to locate a bomb in the London underground guided by text messaging and visual clues. Typically, the frame for an AR game is a dramatic story that presents a problem the students are asked to solve, such as finding the source of pollution in a stream or the root causes of a riot on a college campus during the Vietnam era. The virtual location for the simulation is mapped onto the students' physical location (e.g., soccer field, playground). The students are out on location with handheld GPS-enabled devices or smart phones. They see themselves as icons on a map on their devices. Each student on a team is designated to take on a different role and only they receive certain informational clues. Therefore, to solve the problem, they must communicate and collaborate. As they move through their environment, hot spots will trigger clues that are sent to their devices, they "encounter" people whom they interview, and they acquire data, statistics, virtual photos, and other resources, which provide evidence for solving their problem. These quasi-fictional simulations can be very engaging to students.[37]

In the AR games developed by the University of Wisconsin, Madison, K-12 students took on real-life roles and encountered authentic challenges. Holding a handheld devices with global positioning systems (GPS), they walked about in their communities, while viewing themselves as an icon moving on a map. At various locations they "met" and interviewed virtual people and accessed virtual photos, statistics, and other documents that added to or "augmented" reality they saw in the ordinary world. Players thus experienced a virtual world layered on top of a real-world context. Different roles received different information, so that collaboration among players was essential. In the end, they used this information to identify various points of view, developed arguments, and presented and defended their conclusions. They attempted to piece these clues together, form hypotheses, further analyze data, and heatedly debated the merits of their latest hypothesis to see if it fit with their growing body of evidence. Students used both logic and creativity as they struggled to make sense of the evidence and solve the challenge. Students were typically engaged and motivated as they participated in constructive argumentation (i.e., heated discussions that presented various perspectives and evidence on a particular position).

Much of what has been learned to date linking AR to learning has been through descriptive studies. For example, the study by researchers at the University of Wisconsin, Madison investigated the use of an AR simulation called Mad City Mystery. The research involved 18 elementary schools, 10 secondary schools, and 6 graduate students in separate sessions of 2-3 hours of game playing. The purpose was for teams of students to investigate the cause of death of one of their virtual colleagues, based on evidence made available to them as they searched the crime scene (a lake front in the neighborhood of their school). The game was mapped to their local environment through GPS to set the context for the investigation. The researchers reported that this AR mystery immersed students in collaborative investigation and scientific argumentation not often achieved in

the classroom. The researchers surmised that the interaction of five factors combined to increase student enthusiasm for science, inquiry, and their local communities. The five factors were: task (a problem to solve); social configurations (roles); embedded resources (text and visual clues sent to them on their mobile devices); context (or place); and encompassing activity system (hot zones that trigger clues).[37]

The power of AR simulations is only now emerging as educators begin to identify instructional designs that leverage this new technology. Experts hypothesize that this type of hybrid learning, which bridges the digital and physical worlds, engages students in highly collaborative learning that advances higher order thinking, problem solving, and communication.[50] The experimental studies described above provide some evidence in support of their hypotheses.

SUMMARIES OF RESEARCH STUDIES ON AUGMENTED REALITY (AR)*

*Not intended to be comprehensive.

- **AR in science (Lithuania).** In 2007, a study was conducted by researchers from the University of Siauliai, Lithuania, on the use of augmented reality with 110 seventh grade students studying the digestive system. Three groups were studied. Group 1 used augmented reality, which included a combined view of the real world and the virtual world; opportunities to interact with real objects; and access to traditional resources. Group 2 used computer-assisted instruction, in combination with traditional resources. Group 3 used traditional teaching (e.g., textbooks, the Internet, encyclopedias, teachers' help), serving as the control group. The results of the study, across four specific topics within the digestive system, resulted in statistically significant gains by the augmented reality group in comparison to the control group, but only marginal gains by the computer-assisted instruction group in comparison to the controls.[51]
- **Medieval Amsterdam (Netherlands).** Secondary students used smart phone, videophones, and GPS technology to explore medieval Amsterdam. Team members were assigned identities with different rights and rank, such as beggars or merchants, which provided various perspectives on city life in medieval times. Results showed significant gains in pupil knowledge in comparison to a control group, however there was no impact on motivation to study history of the Middle Ages. The researchers commented that it was not clear in their study which aspect of the AR simulation (i.e., the location, the AR, etc.) accounted for the results.[52]

Table 9. Research in Learning through Augmented Reality (AR)

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+				
Correlational or Descriptive/Correlational	+	+	+	+	+

NOTE: "+" indicates primarily promising findings;"+ –" indicates mixed findings; and "–" indicates primarily negative findings.

VIRTUAL WORLDS

Virtual Worlds are immersive 3-D environments in which users are visually represented by avatars. The users, through their avatars, visually interact and communicate via chat, and are able to “act” upon their world as they move, learn, communicate, build objects, and interact socially within that environment.

Often referred to as multi-user virtual environments (MUVEs), virtual worlds have become more common in the first decade of the 21st Century, due in part to the increased capacity of today’s computers and the general availability of high-speed bandwidth. By far the most commonly used virtual world by users of all ages is Second Life (SL). Created by Linden Lab in 1999 and opened to the public in 2003, it has more than 10 million users worldwide. Education institutions often establish islands in SL for immersive teaching and learning by faculty and students. Teen Grid is a section of Second Life that is restricted to users aged 13-17.

The 3-D worlds provide unique opportunities for teachers and learners, who are often located at a distance, to interact and learn in real-time using non-verbal communication (e.g., emotions and gestures) that personalize and facilitate communication. In other cases, 3-D worlds may be restricted to local area networks within schools, allowing students who may be physically located in the same school to explore and learn in immersive environments.

Most of the research on virtual worlds to date has been descriptive. That research generally indicates that students like the experience of the 3-D environment (e.g., flying, virtual field trips, simulated experiences), with some negative experiences due to technical difficulties and lack of social structure for interactions.[53] Most studies indicated that the immersive worlds resulted in significant social interactions and communication. An outgrowth of out-of-school gaming by adolescents and adults is the acquisition of literacy practices that strongly support school-based literacy goals. For example, students interact within the game in continuous dialog, letter writing, and social interactions. In addition, such practices spill out into the real world with blogs, fan sites, and argumentation on social networking sites. The education community is only now beginning to tap into the literacy side of gaming to advance formal learning.[54,55]

According to Harvard professor Chris Dede, “immersive influences can aid in designing educational experiences that build on students’ digital fluency to promote engagement, learning, and transfer from classroom to real-world settings.”[56] He goes on to say that, such experiences also provide opportunities for students to view complex issues from multiple perspectives. Several studies to date have linked the use of MUVEs to increases in students’ academic performances.

One of the things that remains unclear is the degree of digital immersion that optimizes various types of learning, engagement, and transfer.[56] This is in part because educators are not expert in the use of instructional approaches related to immersive environments, (i.e., learning through role-playing versus learning by doing or learning about).

Researchers indicate that it remains unclear as to whether the 3-D environment or the instructional strategy contributed to reported effects. Experts suggest that more nuanced research using mixed methods is needed to understand fully the impact of various levels of immersive environments in combination with a range of instructional approaches.[57]

SUMMARIES OF RESEARCH STUDIES ON VIRTUAL WORLDS*

*Not intended to be comprehensive.

- **Quest Atlantis.** In 2008, an experimental study was conducted on the use of a multi-user virtual environment (MUVE) video game called Quest Atlantis by sixth grade students. The treatment group studied water quality through the MUVE, while the comparison group used more traditional learning strategies. The results from this randomized controlled trial indicated a statistically significant gain in achievement by the MUVE treatment group in comparison to the control group. The gain was sustained over time as evidenced by a delayed post-test.[58]

- **Software agents as learning partners.** A 2007 study showed that the use of a software agent (i.e., iconic representation that projects running commentary and suggestions) as a learning partner within a MUVE resulted in increased ability on the part of the student to generate effective explanations in science. That study did not find statistically significant differences with respect to academic outcomes for students between the two groups.[59]

Table 10. Research in Learning through Virtual Worlds

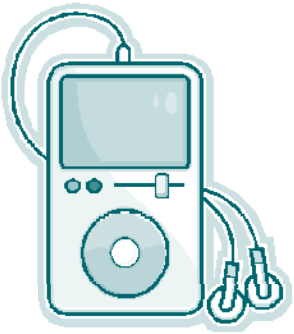
	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+ –				
Correlational or Descriptive/Correlational	+	+	+	+	+

NOTE: "+" indicates primarily promising findings;"+ –" indicates mixed findings; and "–" indicates primarily negative findings.

MOBILE DEVICES

Over the past decade, mobile devices – portable technologies that can be held in the hand and can therefore be used ubiquitously – have transformed radically. These devices, which include tools such as cell phones, media players, and gaming platforms, have witnessed a rapid increase in power and functionality accompanied by an equally significant decrease in size and price. As a result, mobile learning has grown from a minor research interest to a focus of numerous projects worldwide.

Overall, the research suggests that using handheld devices can considerably enhance student learning. The quantity of research behind this claim is exemplified by numerous literature reviews and discipline overviews, as well as annual proceedings from The International Association for Mobile Learning's mLearn conferences.[60,61,28,62] The research is diverse, varying in key issues such as device, subject matter, and student population. Projects using handheld computers with elementary aged children, for example, range from specific subject matter studies on the environment in Singapore[63] and math in Hong Kong[64] to a large-scale implementation of general curriculum in the UK.[65] More recently, iPod devices are being assessed in their ability to assist learning in subjects such as math[66] and reading[67], and games on Nintendo's pervasive DS have also shown potential in these core curriculum areas.[68,69]



Clear themes have emerged across the various research topics described above. The mobile learning community has demonstrated that handheld devices offer five key opportunities:[62]

1. They encourage anywhere, anytime learning, allowing for situated learning and bridging the gap between school and other environments. Context-aware mobile learning, which ties learning to place and embeds virtual information and experiences, is a particular theme here.[70,71]
2. They reach underserved children, providing new learning opportunities to individuals, communities, and countries that are especially challenged — either socially or geographically.[72,73]
3. They improve social interactions deemed essential for 21st century success, such as collaboration and language learning.[74]
4. They fit with learning environments, both in classroom settings and informal learning environments such as museums.[75,76]
5. They enable a personalized learning experience, facilitating the one-to-one paradigm and targeting learning to individuals.[67]

Despite these positive themes emerging from the rapidly intensifying research focus on mobile learning, there is currently a lack of rigorous research in the field, and most of the aforementioned studies are descriptive. In fact, a recent review of research methodologies used in studies on mobile handheld devices in K-12 and higher education settings indicated that descriptive research was by far the most common method (66%), with only 5% of studies being truly experimental.[60] Nevertheless, there are a number of rigorous research studies that prove the viability of mobile learning, and inevitably more will transpire as the field matures.

Few technology sectors have advanced as prominently as handheld devices, and this progression provides unique opportunities to enrich teaching and learning. Educational researchers have begun to generate a body of work that substantiates this potential, however the studies in this relatively new discipline are mostly descriptive and more rigorous research is required. Nevertheless, positive results suggest that it is possible to achieve significant learning benefits using handheld devices when the technology implementation is combined with sound pedagogy and educator training and support.

SUMMARIES OF RESEARCH STUDIES ON MOBILE DEVICES*

*Not intended to be comprehensive.

- **Mobile computer supported collaborative learning (Chile).** Researchers used a mobile computer supported collaborative learning system that promoted student collaboration and constructivism. The system was tested to teach physics at the secondary school level, math at the primary level, and vocabulary amongst first-graders. Statistically significant positive results were observed in each case. [77-79]

- **Effectiveness of vocabulary learning via mobile phone (Taiwan).** Researchers examined the effectiveness of short messaging services (SMS)-delivered English vocabulary lessons on mobile phones amongst high-school students. Overall results were positive, as students recognized more vocabulary after reading the regular and brief SMS lessons than they did after reading the relatively more detailed print material.[80]

Table 11. Research in Learning through Mobile Devices

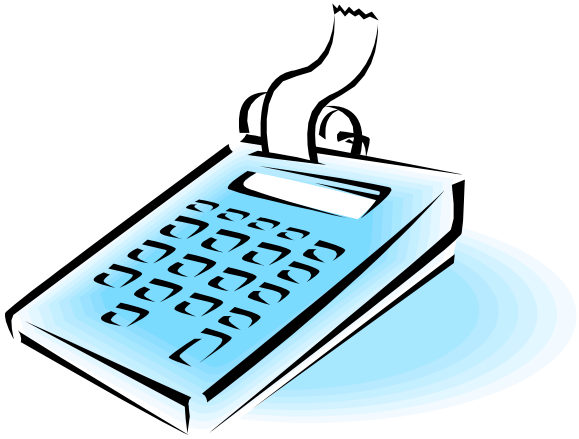
	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+				+
Correlational or Descriptive/Correlational	+	+	+	+	+

NOTE: "+" indicates primarily promising findings;"+ –" indicates mixed findings; and "–" indicates primarily negative findings.

CALCULATORS

Historically, research on the use of basic calculators in mathematics classes has been mixed. However, after the graphing calculator was introduced in the 1980s, results were increasingly more positive for students in college-track mathematics.

A 1997 study conducted in England reported that national policies differed considerably. Denmark, Norway, Portugal, and Sweden adopted a centralized view that calculators should be an established component of the curriculum; England, Italy, Poland, and Spain left the decision up to individual schools and teachers; and Austria, former West Germany, and Switzerland discouraged calculator use in secondary schools.[81]



The National Council for Teachers of Mathematics (NCTM) credited the graphing calculator for "the emergence of a new classroom dynamic in which teachers and students become natural partners in developing mathematics ideas and solving mathematical problems," especially in algebra and higher mathematics.[82]

In general, the literature suggests that the use of calculators improves learning in three areas: understanding of graphical concepts; the ability to make meaningful connections between functions and their graphs; and enhanced spatial skills.[83] A recent meta-analysis found that when calculators are an integral part of testing and instruction, students' operational and problem-solving skills improve. However, further research is needed to make any definitive claims on the retention and transfer of mathematics skills when calculators are used.[84]

SUMMARIES OF RESEARCH STUDIES ON CALCULATORS*

*Not intended to be comprehensive.

- **Multiplication and calculator use.** A recent study tested third graders' performance on multiplication problems after spending a class period working on practice multiplication problems. Some students worked on the problems without a calculator, while others simply plugged the equation into a calculator to generate the answers. Students were permitted to check their answers with calculators. The researchers found that for students who were not good at multiplying, generating the answers on their own, without the use of a calculator, helped their performance on subsequent tests. However, for the students who did not know many multiplication facts, the use of the calculator negatively impacted their performance. For students who knew some multiplication facts, using the calculator before taking the test had no impact.[85]

- **SAT performance and calculator use.** In a large-scale study by the Educational Testing Service (ETS), U.S. college-bound juniors who were permitted to use calculators did significantly better on a test with items drawn from the SAT than students who were not allowed to use calculators. Questions for the exam were selected to be more sensitive to calculator effects than the actual SAT. Three out of four ethnic groups (Whites, African-Americans, and Asian-Americans) and both genders benefited equally from calculator use, while Latinos benefited slightly more than the other groups.[86]
- **Middle school math and calculator use.** A 1998 study investigated the value of providing access to calculators and of providing instruction on how to use calculators (in addition to access) for increasing middle school students' math test scores. The study found that seventh and eighth-grade students who used calculators outperformed students who did not on a test of basic math skills, regardless of whether or not the students were instructed in how to use the calculators.[87]

Studies suggest that the power of this technology for learning mathematics is unleashed when the tools are used long-term (more than nine weeks); are integral to the instruction, not just computational tools; and are used in both instruction and assessment activities. However, research indicates that using calculators in multiplication lessons can negatively impact students if they do not know many multiplication facts.

Table 12. Research in Learning through Calculators

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+ −	+	+		+
Correlational or Descriptive/Correlational	+ −		+		+

NOTE: "+" indicates primarily promising findings;"+ −" indicates mixed findings; and "−" indicates primarily negative findings.

1:1 RATIO OF COMPUTERS TO STUDENTS

1:1 computing refers to situations where each student and teacher has access to the use of a personal laptop computer, typically with wireless access. In some cases, laptops are checked out to students for 24 hours a day, 7 days a week (24/7). In other cases, students may be restricted to in-school only use, where laptops are checked out to individual students, but recharged at night in a cart; or students may have periodic access to a laptop from sets of computers on rolling carts.

Policymakers around the world are investing large sums of money in laptop computers for students and teachers in elementary and secondary schools. For example, Portugal is providing 500,000 computers to students and Venezuela has ordered 1 million laptops for children. In the United States, the states of Maine and Pennsylvania have invested in 1:1 wireless laptops for large cohorts of students statewide, and many other states, districts, and schools support 1:1 laptops or mobile carts that provide a 1:1 ratio in selected classrooms. The diminishing cost of wireless laptops is fueling the growth of 1:1 programs—but policymakers should understand there are other significant cost elements, such as technical support and teacher training.

Major reasons given for supporting 1:1 programs include: (1) economic arguments, based on creating a better educated work force and attracting new jobs; (2) equity concerns, to support students from low-income families whose access to technology and information is restricted; and (3) education reform, as policymakers attempt to make schools more effective and appropriate to people's needs in the 21st century.

Many descriptive studies report that 1:1 deployments increase students' engagement in learning. These 1:1 programs usually prove popular with students, teachers, parents, and administrators, who typically report that the laptops provide a wide range of educational benefits. There are fewer rigorous studies of 1:1 laptop programs than one would hope, particularly those including a large sample, quantitative student outcome measures, and a control or comparison group.

A frequently reported outcome of research is that programs providing computers to schools increase the technology skills of teachers and students. Rigorous studies also show that students in 1:1 programs write more and their writing is better than comparison students in conventional classrooms. Research shows that students use laptops frequently to search for information of various kinds. However, there is little evidence of the effectiveness of large-scale laptop programs in most learning domains.[88]

Successful laptop programs must be part of balanced, comprehensive initiatives that focus on education goals, curricula, teacher professional development, and student assessment practices. A laptop program can contribute to achieving larger education reform goals. At the same time, providing teachers and students with laptops, in isolation, is not likely to be a sufficiently strong intervention to change patterns of teaching and learning significantly for the better.

SUMMARIES OF RESEARCH STUDIES ON 1:1 RATIO OF COMPUTERS TO STUDENTS*

*Not intended to be comprehensive.

- **Texas Technology Immersion Pilot (eTxTIP)**. A 2008 study in Texas compared the results from 20 schools implementing laptop programs and a matched comparison group of schools that did not use laptops. The study showed positive impacts of laptops on technology use and proficiency, increased interest among teachers in student-centered instruction, reduced student disciplinary actions, and greater teacher collaboration. However, there was no significant impact on students' test scores in reading and writing, and a weak impact in mathematics.[89]
- **Cross-national study on PD**. A large cross-national study conducted in 2008 reinforced the importance of professional development (PD) to the outcomes in 1:1 learning, finding that teachers' competence using technology, as well as the amount of their training in uses of technology for instruction, were both associated with greater use of technology for instruction in 1:2 situations.[90]
- **Campbell Collaboration meta-analysis.** In 2008, the Campbell Collaboration commissioned another meta-analysis of rigorous research on 1:1 laptop programs. As with the 2006 synthesis, this study found positive effects on students' writing skills but no impacts on achievement in other academic areas.[91]
- **Meta-analysis**. A 2006 synthesis of research on 1:1 laptop programs uncovered few outcome studies with rigorous designs, but studies that did measure outcomes consistently reported positive effects on technology use, technology literacy, and writing skills.[92]

Computing Table 13. Research in Learning through 1:1 Ratio Of Computers To Students

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+ Writing − Other	+ −	+	+ −	+
Correlational or Descriptive/Correlational	+	+ −	+	+ −	+

NOTE: "+" indicates mostly positive or promising findings, "+ −" indicates mixed findings, and "−" indicates mostly negative findings.

VIRTUAL LEARNING

Virtual learning refers to a learning process where the teacher, trainer, facilitator and learners are geographically distant from each other. Learners are not together in a real or actual learning venue such as a class, but in a virtual learning environment made possible by the use of various technological tools. The types of virtual learning range from supplementary to comprehensive, from synchronous to asynchronous, from audio to web-based or video-conferenced, as well as innovative hybrids thereof.

Virtual learning is experiencing significant growth among the nation's elementary and secondary school students, fueled by the increase in high speed Internet access and Web 2.0 tools.[93] Unfortunately, research on the topic has not kept pace. The body of published, rigorous research related to the effectiveness of this medium is relatively small, and is generally limited to the effectiveness of distance education in comparison to the traditional classroom learning. There is a lack of more nuanced studies that might lend insight into the factors that contribute to or inhibit learning in virtual environments.[94,95]

Beginning in 1999, several meta-analyses have been conducted in an attempt to measure the effectiveness of online learning.[96,95,97-100] In 2005, *Learning Point Associates* reviewed several meta-analyses conducted before 2004 and concluded that, based on the findings from the five previous studies, online learning can be as effective as classroom-based learning, but that more research is necessary.[101] In 2007, the Florida TaxWatch Center for Educational Performance and Accountability conducted a study on the effectiveness of the Florida Virtual High School (FVHS) in comparison to traditional schools. The report indicated that, "students in the FVHS outperformed their statewide counterparts on two independent assessments, both the Florida Comprehensive Assessment Test (FCAT) and Advanced Placement (AP) examinations." The report also noted the low costs associated with the provision of courses through FVHS.[102] However, the report did not use a comparison group that was specifically matched to the FVHS students, nor did it take into account the relatively high percentage of FVHS students who withdrew prior to completing 50% of their courses. Thus, the results must be interpreted with these caveats in mind.

Although one study reported no differences in achievement outcomes, it did find a small difference in attitude outcomes, with students in traditional classes reporting slightly more positive attitude scores.[96] Summaries also indicate that gains in student achievement in courses using email and web-based virtual learning were slightly better than in courses using traditional instruction, while gains in student achievement in courses with video-based virtual learning were either the same or slightly lower than traditional instruction. A recent report on visualization and learning through multimedia from the UK suggests that virtual learning results will be determined somewhat by learner control, dialogue, learner support, and opportunities for direct learner involvement.[103] Currently nuanced studies that differentiate findings based on these characteristics are not available.

An interesting extension of virtual learning is the intelligent tutoring system (ITS). Two critical elements of an ITS are: it allows for either the student or the tutor to ask open-ended questions and initiate instructional dialogue; and it generates instructional materials and interactions upon demand, dynamically, rather than simply accessing stored programs

With some exceptions, the available research on the effectiveness of virtual learning compared to traditional classroom learning has found that virtual learning is as effective as traditional learning for academic achievement "when classes are well-planned, well-taught, and matched to student needs. Effectiveness of virtual learning appears to have more to do with who is teaching, who is learning, and how that learning is accomplished, and less to do with the medium."[104]

SUMMARIES OF RESEARCH STUDIES ON VIRTUAL LEARNING*

*Not intended to be comprehensive.

- **Department of Education.** In 2009, the U.S. Department of Education released a meta-analysis and literature review of 51 studies on virtual learning. They found that "on average, students in online learning conditions performed better than those receiving face-to-face instruction."[105] However, 44 of the 51 studies included dealt with college-level courses, prompting ED officials to caution against generalizing the report's findings to the K-12 level.[105]

- **Microcomputer Based Laboratory (MBL).** In a 2006 study, the academic achievement in physics of high school students taking an online, hands-on Microcomputer Based Laboratory (MBL) unit on motion was compared to that of students in a more traditional MBL classroom setting with a teacher. The online students showed significant comprehension gains from pre- to post-test, paralleling those of the students in the control group. The authors suggest that the study indicates that students who do not have access to face-to-face courses in physics should consider the online MBL course.[106]

- **Meta-analysis.** A 2004 meta-analysis on virtual learning found a slightly positive effect in learning when comparing web-based virtual learning courses versus traditional schooling. However, that same analysis detected a slightly negative impact on student learning when videoconferencing was used as a delivery mechanism.[97] Another meta-analysis from the same year also compared students taking online courses with conventional courses. This study included primary and secondary schools, and institutions of higher education. Researchers found no significant differences in comparisons, between either conventional teaching and online learning, or conventional teaching and videoconferencing. The authors of the study also noted that, while online learners slightly outperformed conventional classroom students, they had lower class retention rates; and that conventional students did outperform videoconferencing students, although the differences were not significant.[96]

Table 14. Research in Learning through Virtual Learning

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+ −	+	+	+	+
Correlational or Descriptive/Correlational	+		+	+	+

NOTE: "+" indicates primarily promising findings;"+ −" indicates mixed findings; and "−" indicates primarily negative findings.

DATA VISUALIZATION/ANALYSIS TOOLS

As reported in the earlier version of this report, there is a small but compelling body of research that consistently links the use of technology to students' ability to collect, analyze, and represent data with significant, occasionally startling, gains in student learning. This family of technology tools includes the following:

- Tools for collecting data
- Tools for analyzing data
- Tools for visualizing data

Tools for collecting data

The collection of data in the traditional classroom has been limited to approaches such as "cookbook" style experiments in science where thermometers and litmus paper are applied in processes. In such cases, the goal is not truly experimental, but rather to approximate the findings mysteriously hidden in the back of the teacher manual. In the social sciences, if any data collection at all is attempted, it is typically limited to family or in-class surveys displayed in handmade bar charts. With the advent of electronic probes and "probeware" in science, data can be collected and displayed in real time, allowing students to observe not only the outcome of experimental processes, but also the progression of those processes as the elements of the experiment interact. In the social sciences, online survey tools such as Zoomerang and SurveyMonkey, combined with access to email and online collaborative services like the iEarn project, can open the door for students to do original research collecting data as similar to professionals.

Tools for analyzing data

Students in today's schools often have access to the same or similar tools for data analysis as those used by professionals in the field. The ubiquitous spreadsheet tool, Microsoft Excel, is used in science and math programs throughout the nation. For more advanced secondary students, programs such as the online StatCrunch can allow them to conduct analyses formerly limited to only the most sophisticated, and expensive, professional data analysis tools. In addition, free data analyses tools are proliferating on the Web and the savvy teacher or student can likely find such a tool along with the background instructions needed to implement the procedure.

Tools for visualizing data

Tools for data visualization cover a large range of uses and styles. They can be age appropriate graphing programs; spreadsheets; or sophisticated data visualization tools, which make apparent findings of a data collection initiative, and, through interactive characteristics, the relationships between the variables and elements of the data. As described below, there is an emerging body of evidence that suggests that these tools can help students deepen their understanding of complex concepts. This is particularly true in math and science where, by changing parameters in their data

analysis, students can observe the impact of those changes on the graphic representation of the data.

While most of the literature related to collecting and analyzing data is descriptive and tends to focus on tools and strategies, there is a small body of evidence relating data analysis and visualization tools to student achievement.

SUMMARIES OF RESEARCH STUDIES ON DATA VISUALIZATION/ANALYSIS TOOLS*

*Not intended to be comprehensive.

- **Korea.** In Korea, a study compared grade 11 students who used graphing calculators with those studying force and motion through more traditional lecture/demonstration-based instruction. The students using the graphing calculators, particularly a subgroup of those students who used calculators designed to graph experiments in real time, significantly outperformed controls.[107]

- **Cyprus.** In a small study in Cyprus, grade 4 students studied transformation of matter (freezing and thawing) within the national science physics curriculum. Students were randomly assigned to three groups; one treatment and two controls. The treatment group studied the physical principles through an inquiry-based approach with all data collection and graphing done on computers using probes and graphing software. The first control group followed an inquiry-based approach but used manual methods to gather and graph data. The second control group followed the lesson plans in the national curriculum that prescribed the use of teacher-led discussions and demonstrations as the primary means of instruction with no student collection or analysis of data. The assessment used in the study was a collection of written, open-ended questions, each scored with a rubric, with all scoring validated by a panel of physicists. The results of the study were both impressive and somewhat surprising. The treatment group significantly outscored both control groups, almost doubling the growth of each of the controls. However, the control group that used the same inquiry-based curriculum as the treatment performed about the same as the control group w more traditional instructional strategies. The authors of the study attributed the difference directly to the use of the computer-based data visualization processes.[108]

- **Jordan.** In a small, but well-reviewed quasi-experimental study conducted in Jordan, some of the students in a single classroom used the popular math visualization program "Geometer's Sketchpad." They significantly outperformed students taught by the same teacher; the only difference in the curriculum was the use of that program.[109]

Table 15. Research in Learning through Data Visualization/Analysis Tools

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+	+			
Correlational or Descriptive/Correlational	+	+	+		+

NOTE: "+" indicates primarily promising findings;"+ –" indicates mixed findings; and "–" indicates primarily negative findings.

COMPUTER ASSISTED INSTRUCTION (CAI)

Computer assisted instruction (CAI) is defined as software or websites where instruction or remediation is presented via a computer. Table 16 shows the effectiveness ratings given by the What Works Clearinghouse (WWC) for software programs.

The Improvement Index column represents the difference between the percentile rank of the average student in the intervention condition and the percentile rank of the average student in the comparison condition. It can take on values between –50 and +50, with positive numbers denoting results favorable to the intervention group.

Table 16. What Works Clearinghouse – Reviews of technology products

Area or Subject/Level	Intervention Program	Evidence Rating	Improvement Index
Alphabetics (K-2)	Earobics	Positive Effects	25
Alphabetics (K-2)	DaisyQuest	Positive Effects	23
Alphabetics (K-2)	Fast ForWord	Positive Effects	8
Alphabetics (K-2)	Early Intervention in Reading	Potentially Positive	36
Alphabetics (K-2)	Waterford Early Reading Program	Potentially Positive	19
Alphabetics (K-2)	Lindamood Phonemic Sequencing (LiPS)	Potentially Positive	17
Alphabetics (K-2)	Read, Write & Type!	Potentially Positive	8
Alphabetics (K-2)	Voyager Universal Literacy System	Potentially Positive	11
Alphabetics (K-2)	Failure Free Reading	No Discernable Effects	1
Reading Comprehension (K-2)	Early Intervention in Reading	Potentially Positive	18
Reading Comprehension (K-2)	Failure Free Reading	Potentially Positive	10
Reading Comprehension (K-2)	Accelerated Reader	Mixed Effects	0
Reading Comprehension (K-2)	Fast ForWord	Mixed Effects	1

Area or Subject/Level	Intervention Program	Evidence Rating	Improvement Index
Reading Comprehension (K-2)	Waterford Early Reading Program	No Discernable Effects	4
Reading Comprehension (K-2)	Lindamood Phonemic Sequencing	No Discernable Effects	6
Reading Comprehension (K-2)	Read, Write & Type!	No Discernable Effects	3
Early Childhood Education Math	SRA Real Math Building Blocks	Positive Effects	36
Early Childhood Education Oral Language	Words and Concepts	No Discernable Effects	4
Early Childhood Education Oral Language	Waterford Early Reading Level One	No Discernable Effects	0
Early Childhood Education Phonological Processing	DaisyQuest for Preschool Children	Positive Effects	25
Early Childhood Education Print Knowledge	Waterford Early Reading Level One	No Discernable Effects	7
Elementary Math	Houghton Mifflin Math	No Discernable Effects	0
Elementary ELL English Language Development	Fast ForWord Language	Potentially Positive	31
Elementary ELL English Language Development	Arthur Educational Television Program	Potentially Positive	11
Elementary ELL Reading Achievement	Reading Mastery	Potentially Positive	28
Elementary ELL Reading Achievement	Fast ForWord Language	Potentially Positive	3
Elementary ELL Reading Achievement	Read Naturally	No Discernable Effects	0
Middle School Math	I CAN Learn Pre-Algebra and Algebra	Positive Effects	5
Middle School Math	The Expert Mathematician	Potentially Positive	14
Middle School Math	Cognitive Tutor Algebra I	Potentially Positive	8
Middle School Math	Transition Math	Mixed Effects	0
Middle School Math	Connected Math Project	Mixed Effects	-2
Middle School Math	Accelerated Math	No Discernable Effects	4

Area or Subject/Level	Intervention Program	Evidence Rating	Improvement Index
Middle School Math	University of Chicago School Math Project	No Discernable Effects	-6

NOTE: An additional 94 software products were reviewed but not rated since no associated research studies to date were located by the WWC.

SUMMARIES OF RESEARCH STUDIES ON COMPUTER ASSISTED INSTRUCTION (CAI)*

*Not intended to be comprehensive.

- **IES longitudinal study.**[110] In 2009, the U.S. Institute of Education Sciences (IES) released the second year results from their two-year longitudinal study on the impact of software products used to support reading and math instruction. The first year the study focused on the use of 16 products in early literacy and middle grade mathematics. The effects of the technology products were found to be not statistically different from zero. The second year focused on two objectives: to assess whether a second year of experience with a software product resulted in increased student scores, and to report on the effectiveness of the product in increasing test scores. The second year continued with 10 products, with continued implementation in 23 districts, 77 schools, with 176 teachers and 3,280 students. For the first objective, the results were mixed. In the second year, for reading there were no statistically significant differences between effects from the first to the second year. For grade 6 mathematics, the results in the second year were significantly lower than in year 1. For Algebra I the effects in the second year were significantly higher than in year one. The study also reported on the effects of the 10 software products on student test scores. One product (LeapTrack at the grade 4 level) has a statistically positive impact. Nine products had no statistically significant impact on student scores. Of the nine insignificant effects, five were negative (Grade 4 Academy of Reading, Grade 6 PLATO/Achieve Now, Larsons Algebra I, and Cognitive Tutor Algebra I) and four were positive (Grade 1 Destination Reading, Headsprout, and PLATO; Grade 6 Larsons Pre-Algebra I). The study's authors provide the following limitations to the findings:

> "The study's findings should be interpreted in the context of its design and objectives. It examined a range of reading and math software products in a range of diverse school districts and schools. But it did not study many forms of educational technology and it did not include many types of software products. How much information the findings provide about the effectiveness of products that are not in the study is an open question. Products in the study also were implemented in a specific set of districts and schools, and other districts and schools may have different experiences with the products. The findings should be viewed as one element within a larger set of research studies that have explored the effectiveness of software products."[110]

Table 17. Research in Learning through Computer Assisted Instruction (CAI)

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+ −	+ −			
Correlational or Descriptive/Correlational	+ −	+ −	+	+	+

NOTE: "+" indicates primarily promising findings;"+ −" indicates mixed findings; and "−" indicates primarily negative findings.

EDUCATIONAL TELEVISION

Educational television refers primarily to programs or videos that emphasize formal classroom instruction, and enrichment programming. Similarly, educational video is any video programming that contributes to the teaching/learning environment.

Decades of research on children's television have indicated that television can be an effective instructional tool when the content is educational or repurposed for education. A sound body of research shows that when programs are designed to fit the cognitive demands of specific ages, children can benefit from viewing and interacting with educational television and video. Furthermore, although watching television or videos was once thought to be a passive process, cognitive research has shown that viewers observe, interpret, and coordinate all the information while viewing and make their own personal sense of what is being communicated.[111]

Numerous research studies show that educational television can have positive effects on the intellectual and academic development of children. For example, researchers found that *Sesame Street* viewers were better prepared for school than their non-viewing peers.[112] Studies from Yale University found that two and three-year-olds who watched *Barney* gained more social and academic skills than children who did not.[113] More recently, researchers found that watching the television program, *Blue's Clues,* which includes lots of repetition, pointing, and labeling, had strong effects on developing flexible thinking and problem solving skills.[114,115] Another study found that multiple viewing of the same episode of *Blue's Clues* significantly increased transfer.[116]

On the other hand, studies have also found that exposure to television violence can increase the risk of children behaving aggressively and that watching too much television as a child may be related to concentration and attention problems later in life. A recent study by the American Academy of Pediatrics (AAP) found that consistent, heavy television viewing (more than two hours a day) throughout early childhood can cause behavior, sleep, and attention problems.[117] Additionally, some experts argue that watching television may detract from time children spend interacting with family, engaging in physical activity, using their imaginations, or exploring the world around them.[118]

After analyzing 120 episodes across 40 program titles, researchers found that only 1 in 8 children's educational television programs (13%) met high quality standards. Each show was evaluated on several educational criteria associated with children's learning from television, including whether the episode had a primary lesson and how clearly the show conveyed that lesson to children. Of those deemed educational, nearly one of every four (23%) was classified in the lowest category of "minimally educational," while most (63%) were judged to be "moderately educational."[119,23]

The power of television and video for learning lies in the use of multimedia to engage students visually, cognitively, emotionally, socially, and civically in facets of the academic content. Visual learning can result in increased engagement as well as increased complexity, depth, and breadth of experience to improve student academic performances. Results depend on the inclusion of high-quality content and sound pedagogy.

*Not intended to be comprehensive.

- ***Between the Lions* and early literacy skills.** A study on *Between the Lions* examined individual growth rates in phonological awareness and letter-word identification skills for 150 Latino English-language learners. Skills were tested at three different points during one year using a standardized measure of phonological awareness. Before the second and third assessments, one third of the children watched *Between the Lions* three times a week, another third viewed *Arthur*, another popular children's program, and the last third did not view either show. Individual growth modeling analysis showed that children who viewed *Between the Lions* had steeper growth trajectories than those who viewed *Arthur* for several of the phonological awareness measures, suggesting that viewing *Between the Lions* is beneficial to children's early literacy skills.[120]

- ***Sesame Street*.** Some of the earliest and most comprehensive examples of this research focus on the television program *Sesame Street* and its audience of preschool children.[121] These studies show that viewing this program was positively associated with vocabulary and letter and number recognition.[122] Additional research found that children who watched more *Sesame Street* prior to entering school were rated by their teachers as better prepared for school (e.g., greater verbal and quantitative readiness, better attitudes toward school, and better relationships with their peers).[123] In more recent studies, these effects were replicated with low supplemental educational services (SES) children.[122] The benefits of watching *Sesame Street* have been found to hold long-term benefits for viewers as well. A follow-up study with a sample of 15 to 20-year-olds found that those who had been frequent viewers of *Sesame Street* at age five had significantly better grades in English, science, and mathematics; read more books for pleasure; and had a higher motivation to achieve. These students also had more positive academic self-esteem and a better attitude toward academics.[124] Versions of *Sesame Street* adapted for children in other countries have produced similar results in Mexico, Portugal, and Turkey.[125]

Table 18. Research in Learning through Educational Television

	Type of Learning				
	Basic Skills	Higher Level Thinking	Information, Communication, & Technology (ICT)	Collaboration/ Participatory Learning	Engagement in Learning
Experimental or Quasi-Experimental	+		+	+	+
Correlational or Descriptive/Correlational	+	+	+	+	+

NOTE: "+" indicates primarily promising findings;"+ –" indicates mixed findings; and "–" indicates primarily negative findings.

CONCLUSION

The research on the effects of technology on learning is emerging, especially for Web 2.0. Overall, across all uses in all content areas, technology does provide a small, but significant, increase in learning when implemented with fidelity and accompanied by appropriate pedagogical shifts. While this is generally encouraging, the real value lies in the identification of those technology interventions that get significant positive results that warrant investment. Most educators are looking for the value proposition that will significantly advance learning, teaching, and school system efficiencies. Taking advantage of these leverage points requires serious review of specific research studies that address the needs and challenges unique to individual schools, and that pay serious attention to leadership development, professional development, school culture, curricular redesign, and teacher preparation.

The reasons cited for the slow rate of integration of technology in schools vary considerably over time and locale. For many educators, the lack of access to reliable, up-to- date technology is a major barrier to effective use. In schools with sufficient access (e.g., 1:1 environments, schools with laptops on carts, schools with low student-to-computer ratios), the barriers to effective use are lack of: vision; access to research; leadership; teacher proficiency in integrating technology in learning; professional development; innovative school culture; and/or resources. Gains in learning can be accomplished in a variety of classroom configurations.

Challenges for schools include:

- The amount of student access required to achieve gains in learning varies considerably by type of use. For example, an intervention such as FastForword requires high levels of use for a short period of time in order to maximize learning gains; student wikis, blogging, Internet research, data analysis, or writing on word processors is highly facilitated by 1:1 access during the writing, editing, and production process; and comprehensive programs such as Cognitive Tutor Algebra requires that each student dedicate two days each week working individually for a class period on a web-enabled computer. On the other hand, whole class interventions, such as interactive white boards, requires a teacher at a demonstration station to facilitate learning. The challenge for schools is in ensuring adequacy of access and availability of the technology in configurations that fluctuate with teachers' lessons and students' needs.

- Identifying the technology-based interventions that have the potential to bring about higher levels of student achievement is another challenge that schools face. Despite the decades of use of technology in elementary and secondary schools, the number of rigorous research studies is small, the quality of the studies varies considerably, and the level of funding for such research is low in most countries.

- The fidelity of technology integration in schools varies tremendously. Unfortunately, such fidelity is often neither tracked nor reported in research studies, translating into research findings for specific interventions that vary considerably across sites, with such variations left unexplained. For example, there is definitive research on the positive gains in reading accomplished through high-fidelity use of Waterford Early Learning with at-risk students, yet a larger urban school system that invested significant funding in that same intervention has not been able to replicate those gains, partly because of poor fidelity.

The indicators for success are not solely dependent on the level of student access, but rather on the nature of student and teacher use and the fidelity of the implementation. Such fidelity of implementation in a school, in turn, is determined by leadership, teacher proficiency, professional development, curricular fit, school culture, pedagogical approaches—and, on the level, speed, and type of technology and Web 2.0 access. Innovative leadership is needed to ensure progressive school policies on technology and Web 2.0, and other emerging technologies and to facilitate strong links between the formal and informal learning enabled through the Web.

Table 19. Summary of Findings for Various Educaitonal Technologies by Type Of Learning and Type of Research

TECHtypes	*Type of Learning*									
	Basic Skills		Higher Level Thinking		Information, Communication & Technology (ICT)		Collaboration/ Participatory Learning		Engagement in Learning	
	Exp	Corr/ Des	Exp	Corr/ Des	Exp	Corr/Des	Exp	Corr/ Des	Exp	Corr/ Des
Interactive Whiteboards (IWB)	+/-	+		+	+	+	+/-	+	+	+
Classroom Response Systems	+	+		+/-		+/-	+	+		+
Video Games	+	+	+/-			+	+	+	+	+
Simulations		+	+/-	+		+	+	+	+/-	+
Modeling		+	+	+	+	+		+		+
Augmented Reality (AR)	+	+		+		+		+		+
Virtual Worlds	+/-	+		+		+		+		+
Mobile Devices	+	+		+		+		+		+
Calculators	+/-	+/-	+		+	+			+	+
1:1 Ratio Of Computers To Students	+/-	+	+/-	+/-	+	+	+/-	+/-	+	+
Virtual Learning	+/-	+	+		+	+	+	+	+	+
Data Visualization/Analysis Tools	+	+	+	+		+				+
Computer Assisted Instruction (CAI)	+/-	+/-	+/-	+/-		+		+		+
Educational Television	+	+		+	+	+	+	+	+	+

NOTE: "**+**" indicates primarily promising findings;"**+ /–**" indicates mixed findings; and "**–**" indicates primarily negative findings. The "Experimental or Quasi-Experimental" category of research is noted above by "Exp", and the "Correlational or Descriptive" category is noted by "Corr/Des".

APPENDIX: METHODOLOGY

Search strategy for identification of studies

The time period examined was 2005 to 2009, with the last search conducted in May 2009. The primary sources for locating studies were the following three databases: EBSCO, ProQuest, and the Educational Resources Information Center (ERIC). However, since the terms preferred by any individual end-user may not be the same as the terms preferred by the database indexers, an informal search of the online Thesaurus of ERIC Descriptors was initially conducted to locate all possible synonyms and key words.

Broad search terms including, but not limited to *educational technology*, *student learning*, and *student achievement* were combined with the specific applications of technology or tools (e.g., television, video, laptops, etc.). Both controlled terms, i.e., quotes (“ ”) to locate direct phrases, as well as free text terms were used, depending on the database. For example, in ERIC, for the term *game*, there were 2,199 hits. To reduce the magnitude of this review, we used various AND operators to tailor the review to the specific technology of question. Each abstract was reviewed to determine its relevancy with the topic (e.g., K-12 students).

We also expanded our search through the Web to locate more relevant articles. We conducted an Internet-wide search with Google, using the same keywords mentioned above, for the same time. After each search was conducted in all three databases, the search results and number of “hits” were noted. Citations and abstracts were imported and organized into groups in *EndNote*.

Limitations

In searching the literature, the relevant studies were collected as efficiently and effectively as possible. However, the purpose of this study was not to conduct an exhaustive search. The purpose was to locate several studies that frame the current field of research on the use of technology in schools. The research team kept in mind the purpose of the review and used a professional approach to synthesize the literature through summarizing several of the pivotal research studies on the impact of educational technologies on student achievement. A review “is not exhaustive; it is situated, partial… and a critically useful interpretation and unpacking of a problematic that situates the work historically and methodologically.”[126]

While the literature searches were intended to be comprehensive, they were not exhaustive. Hand searches of journals were not performed, and review articles and textbook chapters were not systematically searched. However, important studies known in the field that were missed by the literature search were included in the review.

GLOSSARY

1:1 computing

1:1 computing refers to situations where each student and teacher has access to the use of a personal laptop computer, typically with wireless access. In some cases, laptops are checked out to students for 24 hours a day, 7 days a week (24/7). In other cases students may be restricted to only in-school use, where laptops are checked out to individual students, but recharged at night in a cart; or students have periodic access to laptops from sets of computers on rolling carts.

asynchronous

Literally means "not at the same time." In asynchronous classes, students and teachers use e-mail, listservs or other technologies that allow them to communicate without having to be in the same place at the same time.

audience response systems

See classroom response systems

augmented reality (AR)

The term augmented reality (AR) encompasses experiences where an individual or team interacts in the real world while simultaneously using images, text, visuals, or global satellite positioning that have been mapped to their real world situation. This also encompasses media techniques such as overlays that make aspects of the media being presented clearer. A classic example of augmented reality in media is the yellow first down line in professional football broadcasts; though it does not exist on the field it allows for those watching to have a better understanding of how the game is proceeding then would naturally be possible without augmentation of the image.

Barney & Friends

Barney & Friends is a 1992 children's television show produced in the United States aimed at preschool children. The series features the title character Barney, a purple anthropomorphic Tyrannosaurus Rex, who conveys learning through songs and small dance routines with a friendly, optimistic attitude. Yale researchers Dorothy and Jerome Singer have concluded that episodes contain a great deal of age-appropriate educational material, calling the program a "model of what preschool television should be."

Between the Lions

Between the Lions is a PBS Kids' puppet show designed to promote reading. *Between the Lions* focuses on teaching reading, pronunciation, and grammar skills, and a love of books to young children in a fun, informative way. It explores the many subjects that books can cover and shows how different people may enjoy reading different things. It also demonstrates the value of reference books and the importance of reading in other everyday activities such as using a computer, cooking with a recipe, or finding your way with street signs. The target audience is children 4 to 7 years old.

Blue's Clues

Blue's Clues is an American children's television show that aired on Nickelodeon. It premiered on September 8, 1996, and ran until 2006. The show used a narrative format in the presentation of material, as opposed to the more traditional magazine format (where many different, often unrelated, sketches are shown one after the other as in *Sesame Street*), and structured every episode the same way. *Blue's Clues* became the highest-rated show for preschoolers on commercial television, and received nine Emmy awards. Its efficacy in teaching children using the medium of television has been documented in research studies.

classroom response systems ("clickers")

The category of classroom response systems includes both hardware and software based engagement device usage. Hardware devices include several device types often referred to as "clickers." These clickers have multiple inputs and are disseminated to students during classroom presentations. During presentations questions asking for a response are put onto a display and students are expected to "click" or depress a button corresponding with their answer. A receiving unit then tallies the answers and displays them graphically for the class to see. This allows for real time feedback on student learning along with increased engagement and feedback on the part of the participating students. Software solutions work very similarly to hardware solutions, but instead of a dedicated clicker device students use a local wireless network in tandem with a different, programmable, portable device such as a mobile phone or notebook computer.

clickers
See classroom response systems

computer assisted instruction (CAI)
Computer-assisted-instruction is defined as software or websites where instruction or remediation is presented via a computer.

correlational study
A non-experimental research in which data are collected to determine the relationship between them.

descriptive study
A research study that has the goal of describing what, how, or why something is happening.

distance learning
See virtual education

educational television
Educational television (ETV) refers primarily to programs or videos that emphasize formal, classroom instruction, and enrichment programming.

e-learning
See virtual education

experimental study
A research study that has the goal of determining whether something causes an effect through random assignment to comparison groups.

Florida Virtual School (FLVS)
Founded in 1997 by President and CEO Julie Young, the Florida Virtual School (FLVS) is an American online middle and high school. According to its website, "FLVS is part of the Florida public education system and serves students in all 67 Florida districts. FLVS also serves students, schools, and districts around the nation through tuition-based instruction, curriculum provision, and training." Over 40 classes are offered by FLVS including a wide variety of AP classes.

Game Boy
See *Nintendo DS*

information and communications technology (ICT)
Information and communications technology (ICT) is a term of wide usage in the international community referring to technology concerned with speeding and facilitating the exchange and distribution of information. Major examples of portable ICT devices include laptop computers, mobile phones, personal digital assistants (PDAs) and advanced graphing calculators. Most modern ICT devices are portable, though not necessarily so (i.e., a desktop computer connected to the internet is an ICT device despite lack of portability). ICT in advanced industrialized countries is generally used to refer to Internet and computer-based technology. However, on a global scale ICT also includes satellite links, telegraph, facsimile, and even things taken for granted in the developed world such as telephone access.

interactive white board (IWB)
An interactive white board is a presentation device that is connected to a computer. It allows users to display and manipulate computer images through a digital projector. Users can control the software from the computer or directly from the board, using a pen or highlighting tool to add notations or emphasize the intended object. The teacher or student can run the software directly from the board using their finger as a mouse. All activities performed on the board can be saved, printed out, and distributed to the whole class.

intelligent tutoring system (ITS)
An intelligent tutoring system (ITS) is any computer system that provides direct customized instruction or feedback to students, i.e. without the intervention of human beings, while performing a task.

iPod
Formerly a brand made up solely of portable music players with limited features beyond MP3 playback, iPods are now largely identical to personal digital assistants (PDAs). They are capable of many functions formerly exclusive to personal computers including opening office documents, checking email, and using custom applications. While still primarily a device for video and audio playback, the iPod touch the capabilities of the iPod line expanded greatly to meet the capabilities of the iPhone and other such smartphone devices. See personal digital assistant for more information.

meta-analysis

In statistics, a meta-analysis combines the results of several studies that address a set of related research hypotheses. This is normally done by identification of a common measure of effect size, which is modelled using a form of meta-regression. Resulting overall averages when controlling for study characteristics can be considered meta-effect sizes, which are more powerful estimates of the true effect size than those derived in a single study under a given single set of assumptions and conditions. Meta-analysis allows works as a sample of multiple similar samples, which gives meta-analyses based conclusions better estimates then any of the individual studies would have alone.

microworlds

Microworlds are explorative learning environments, and they are artificial worlds, then, abstract worlds that allow a free combination of possible and impossible concepts.

mobile device

Refers to a pocket-sized, mobile computing device, typically using a small visual display screen for user output and a miniaturized keyboard for user input. In the case of the personal digital assistant (PDA) as well as some “smartphones,” the input and output are combined into a touch-screen interface.

modeling

Models are interactive representations of real-world phenomenon, where users are able to manipulate the underlying structure (i.e., rules, objects, behavior of objects, and rules of operation) of the representation.

Nintendo DS

The *Nintendo DS* is the current iteration of Nintendo’s long running *Game Boy* line of portable gaming systems. The *DS* is a dual-screen, handheld game console developed and manufactured by Nintendo. It was released in 2004 in Canada, the United States, and Japan. The console features a clamshell design, similar to the *Game Boy Advance SP*, with two LCD screens inside. The bottom screen is a touch screen, which can be interacted with through the use of a stylus or finger. The *Nintendo DS* also features a built-in microphone and supports wireless IEEE 802.11 (Wi-Fi) standards. There are a large number of games for the *DS* including many educational games (primarily short, memory-based games and puzzles). Over 100 million Nintendo DS systems have been sold worldwide as of 2008.

personal digital assistant (PDA)

PDAs are mobile computing devices with reduced feature sets paired with drastically reduced size. These devices are typically no more than a few ounces in weight and three to five inches in length. They are differentiated from smart phones in not being able to natively make phone calls (though some can through Wireless Networks using applications), but often retain all the other features of smart phones from internet access (via wireless networks) to applications. For example, the iPod touch, a PDA, has all the capabilities of the iPhone other then the ability to make calls on a cell phone network.

Playstation 2

The *Playstation 2* was originally released in 1999 and is the bestselling video game console of all time with over 136 million consoles sold as of the beginning of 2009. Compared with the *Playstation 3* and *Xbox 360* the *Playstation 2* graphics are lower resolution and less advanced (looking quite similar to the Wii, Nintendo’s current console). The *Playstation 2* has a very extensive library of thousands of games including many educational titles from *Alphabet Circus* (a game designed to let preschoolers interact with letters) to *The Bible Game* (a game which teaches players about the old testament through quizzes and games.) Many of the games for young children use a small camera rather than a controller to allow for direct, augmented reality interaction with objects in the game To avoid issues with young children manipulating controllers.

Playstation 3

The *Playstation 3* is the follow up to the *Playstation 2* and features more advanced graphics and online capability including a full-featured web browser and gaming social network to play games and chat together. This social network has resulted in original creative games such as *Little Big Planet*, which allows players to create their own unique worlds and levels within the game, and share them with friends. Additionally the *Playstation 3* has puzzle games, strategy games and other educational materials, though not as many as the *Playstation 2* due to the *Playstation 2* is much higher installed base.

Sesame Street

Sesame Street is an acclaimed American educational children's television series and a pioneer of the contemporary educational television standard, combining both education and entertainment. *Sesame Street* is well known for its Muppet characters created by Jim Henson. It premiered on November 10, 1969, and is the longest running children's program on American television. It has won numerous awards and seeks to introduce young children to a wide variety of topics from numbers and letters, to emotions and diversity, through songs, humor, and human and puppet characters.

simulation and modeling

Simulation and modeling are often used interchangeably in the literature. In this paper, we make a clear demarcation of the two based upon the nature of the activities that they can support. The demarcation between simulation and modeling is analogous to that between toy cars and Lego bricks (Bliss & Ogborn 1989). Simulations can be classified as models with pre-defined rules of operation and interaction among objects they encompass. Simulations can be used to support exploratory learning activities in which students can explore the simulation by manipulating the variables or parameters provided, but not the underlying theories and rules of operation. In contrast, modeling environments provide students with a greater flexibility to modify models or even construct their own models by creating objects and defining the rules of interaction. Modelling therefore extends the scope of learning from exploratory to encompass more expressive activities (Ogborn & Bliss 1994; Ogborn 1998).[41]

simulations

Simulations are interactive models that emulate real-world phenomenon through pre-defined rules of operation, behavior of objects, and interaction among the objects they encompass.

Sony *Playstation Portable* (PSP)/PSP Go

The *PSP* line of portable video game systems were developed by Sony and released in 2004. Games are contained on small optical discs or downloaded directly to the flash memory from online stores. The *PSP* is capable of connecting to WiFi networks and features a full featured web browser to compliment its media playback abilities. The PSP has hundreds of games, some of which can be considered educational including puzzle games, music creation games, and games based around short math, reading and pattern recognition challenges (often called brain trainers). The *PSP Go* is the second iteration of the *PSP* and will be released in 2009 with enhanced wireless capabilities, more built in memory and no optical drive (meaning all games will be downloaded from Sony's online store).

smartphone

A mobile phone with advanced features such as Internet access, email, video capture, and more. Examples of modern smartphones are the Palm Pre, iPhone, and Google G1 phone.

social networks

A social network service focuses on building online communities of people who share interests and/or activities, or who are interested in exploring the interests and activities of others. Most social network services are web based and provide a variety of ways for users to interact, such as e-mail and instant messaging services. Social networks also usually allow a wide variety of media to be displayed by users from music to imbedded video and applications. In addition to imbedding media into traditional social networks there are also specialized social networks that relate to a specific type of media. Examples of this include Flicker, which allows easy sharing of photos, and YouTube, which allows for easy sharing of videos (which are displayed along with comments from the community at large).

synchronous

A type of two-way communication with virtually no time delay, allowing participants to respond in real time.

TECHtypes

Used in this paper to refer to the specific types or configurations of technologies.

quasi-experimental study

A research study in which (1) an independent variable is directly manipulated to measure its effects on a dependent variable and (2) participants are not randomly assigned to comparison groups.

quick response systems

See audience response systems

video games

Video games are artificially constructed, competitive, technology-based activities with a specific goal, a set of rules, and constraints that are located in a specific context.

virtual education

See virtual learning

virtual learning

Virtual learning refers to instruction in which students and teachers are separated by time and/or location and interact through the use of computers and/or telecommunications technologies. The types of virtual learning range from supplementary to comprehensive, from synchronous to asynchronous, from audio to web-based or videoconferenced, as well as innovative hybrids thereof.

virtual worlds

Virtual worlds are immersive 3-D environments in which users are visually represented by avatars. The users, through their avatars, visually interact and communicate with each other through text or voice chat. Users are also able to take actions, through their avatars, as they move, learn, communicate, build objects and interact socially within the virtual environment. These worlds also persist whether or not any one given avatar is within them allowing for many users to shape the world collaboratively in different ways.

Web 2.0

Web 2.0 refers to what is perceived as a second generation of web development and web design. It is characterized as facilitating communication, information sharing, interoperability, user-centered design, and collaboration on the World Wide Web. It has led to the development and evolution of web-based communities, hosted services, and web applications. Examples include social-networking sites, video-sharing sites, wikis, blogs, mashups, and folksonomies. The term “Web 2.0” was coined by Darcy DiNucci in 1999, in her article “Fragmented Future.” YouTube, Flicker, Facebook, MySpace, Personal Blogs, and Twitter are examples of Web 2.0 sites often used by students.

Xbox/Xbox 360

The *Xbox 360* was released in 2005 and is the follow up to the original *Xbox*, which was released 3 years prior. The *Xbox 360* is a relatively powerful home gaming console capable of playing DVD games. The *Xbox 360* has significantly less games that are educational by design than the *Playstation* systems, the *Nintendo DS,* or the PC. Most of the software is based around first person shooters and other action games. The console does not have access to the internet in the traditional sense, but does have a gaming based social networking service known as *Xbox Live* that allows players to send short text messages to one another and play games together. The *Xbox 360* has sold around 30 million consoles worldwide since its release in 2005.

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