

Connecting the Bits

A reference for using technology in teaching and learning in K-12 schools

Project-Based Learning and Information Technologies

Introduction

Most teachers, at one time or another, give open-ended assignments that allow students some choice over topic and extend over a considerable period of time. Often these assignments call upon students to exercise a broad range of knowledge and skills from various academic and vocational disciplines. Students design, carry out, and report on their own investigations, either alone or in collaboration with others. These kinds of activities are sometimes called project-based learning.

Information technologies can increase the versatility and value of project-based learning. For example, technology makes it possible for individuals and teams to carry out in-depth projects that draw on various media and information resources from throughout the world.

This paper discusses

- project-based learning that makes effective use of information technologies;
- the research foundations and benefits of project-based learning;
- project-based learning in the classroom, including instructional goals, implementation, and student assessment;
- project-based learning, information technologies, and hardware and software;
- professional development needs for implementing technology-enhanced project-based learning;
- an annotated bibliography.

Project-Based Learning that Makes Effective Use of Information Technologies: An Example and Key Characteristics

A Project-Based Learning Example: “Does Cincinnati Need Another Bridge?”

Students of all ages have the knowledge, skills, and interest to work on “authentic” learning tasks—those that involve substantive, real-world problems. Projects into which technology is integrated often involve authentic work. Consider the following example:

Project-based learning:
a summary of an example

When Cincinnati proposed building a new bridge across the Ohio River, teachers and students at Southgate Public Elementary School in nearby Kentucky decided to study the situation. They began by conducting a community survey and then tabulated the results in an electronic spreadsheet. They conducted background research on the history of bridges and the city. Using a computer-based geometry simulation, they reviewed the geometry of bridges and created models of historical bridges. They visited existing bridges and used video cameras to monitor rush-hour traffic. From this video record, they compiled precise statistics on the number and speed of people and vehicles. They then used these statistics to create multimedia simulations of hypothetical new bridge designs.

The Southgate students tested their ideas of bridge geometry by using straws to construct actual model bridges, and they compared the load-bearing capacities of the different models. The students revisited some of Cincinnati’s bridges, this time with an architect, to ask questions not answered by their research. Finally, they submitted a report to the city of Cincinnati (Salisbury 1995).

Key Characteristics of Project-Based Learning

The Cincinnati bridge study illustrates many of the following key characteristics of project-based learning:

Key characteristics

- ***Students have some choice of topic and some control over the content of the project and the extent of their investigations. Students can shape their project to fit their own interests and abilities. For instance, the Cincinnati bridge project included activities for music and art as well as geometry and physical science.***

- *The teacher acts as a facilitator*, designing activities and providing resources and advice to students as they pursue their investigations. It is the students, however, who collect and analyze the information, make discoveries, and report their results.
- *The context for the subject matter is larger than the immediate lesson.* The bridge across the Ohio River was a community issue being discussed in the media. It was of actual concern to students' families.
- *Students conduct research* using multiple sources of information, such as books, online databases, videotapes, interviews (which they can conduct in person or via telecommunications), and their own experiments. Even if their projects are based on the same topic, different students may use considerably different sources of information.
- *The project usually cuts across multiple disciplines.* Students are expected to draw upon a broad range of knowledge and skills and to "stretch" their own ranges. Initially the bridge project was a study of geometric shapes, but it expanded to incorporate statistics, charting, social studies, physics, language arts, and technology.
- *The project extends over a significant period of time*, usually from several class periods to an entire school year. (The Southgate students studied the Cincinnati bridges for six weeks.) Projects enable students to practice the skills they need to become self-disciplined learners. Students plan how to use their time effectively and share resources such as computers, digital cameras, camcorders, and computer network access. One goal of project-based learning is for students to become better managers of their time and other resources.
- *Students design and develop a product, presentation, or performance* that can be used or viewed by others. In the simplest form, students may present the results of their projects in class as reports or posters. Other projects may extend student products beyond the school boundaries in the form of broadcasts, publications, and public events. Students may create products of significant and lasting value, such as environmental assessments or permanent information displays. The primary audience for the Southgate project report was the city of Cincinnati.

- ***A team of people may work on the project.*** The team may consist of an entire class, several classes, or even several remote sites. In these cases, individuals or small groups work on different components of a large task, and their joint efforts are often coordinated through technology. The Southgate project involved fourth, fifth, and sixth graders, who recorded their investigations on shared central computer databases. Multi-site projects often rely on email or videoconferencing to share information and findings.
- ***The project has several instructional goals.*** In addition, students may achieve other unforeseen goals as they explore complex topics from a variety of perspectives.

Research Foundations and Benefits of Project-Based Learning

A Summary of Research on Project-Based Learning

Project-based learning is a versatile approach to instruction that can readily be used in conjunction with other approaches. Teachers who make extensive use of project-based learning are blending a number of educational ideas, each supported by substantial research. Summarized below are some of the main areas of educational research that underlie project-based learning.

Constructivism is an educational theory of learning premised on the idea that students create, or “construct,” their own knowledge in the context of their own experiences.

Constructivism holds that students learn better when they are actively engaged in “doing,” rather than passively engaged in “receiving” knowledge. Project-based learning is one way to create rich learning environments that invite students to construct personal knowledge.

Howard Gardner and David Perkins are co-directors of *Project Zero* at Harvard University, a large and longstanding research project that studies ways to improve content, pedagogy, and assessment in education.

Students learn better when they are “doing”

Gardner's theory of *multiple intelligences*, which he first put forward in 1983, emphasizes the need for personalization of schooling (Gardner 1995). Gardner argues that each person has several different types of intelligence, such as musical intelligence, linguistic intelligence, and logical-mathematical intelligence. Through appropriate education and experience, these various intelligences can be enhanced—a person can develop his or her own individual potential. Gardner strongly supports the use of project-based learning as one approach to create a learning environment that enhances each student's multiple intelligences.

David Perkins's 1992 book, *Smart Schools*, analyzes a number of different educational theories and approaches to education in a way that strongly supports Gardner's theory of multiple intelligences. Perkins's book contains extensive research-based evidence that education can be considerably improved by focusing on higher-order cognitive skills using project-based learning and encouraging more explicit and appropriate teaching for transfer. In other words, student learning is enhanced when students recognize patterns and rules in one situation that they can apply to other, seemingly dissimilar situations.

Inquiry-based learning, or discovery-based learning, often calls on students to generate and test their own hypotheses. The emphasis may be on discovering specific facts or on developing a higher-order understanding of the topic and ideas being explored. Students are encouraged to develop curiosity as a habit and to approach all learning with a disposition toward questioning and systematic investigation. Project-based learning often makes use of inquiry-based teaching methods. Research indicates that hands-on, inquiry-based instruction is generally more effective than traditional didactic presentation in improving students' problem-solving abilities in particular subject domains (Helgeson 1992).

Students generate and test their own hypotheses

A recent large-scale analysis of data from the National Assessment of Educational Progress looked at the effects of using computers in mathematics instruction and found that technology could make a difference, but it depended upon how it was used (Wenglinsky 1998). This study found that for eighth graders, the use of computers to teach higher-order thinking skills was associated with a one-third of a grade-level increase in mathematics achievement; for fourth graders the contribution was about one-tenth of a grade-level improvement.

Students collaborate to complete a project

Cooperative learning and collaborative problem solving frequently engage teams of students as they work to complete a project. Cooperative learning has been shown to be effective in improving academic and social skills; however, successful cooperative learning requires teachers to organize carefully and, in some cases, to give students explicit training in collaboration and communication (Johnson 1986; Johnson and Johnson 1989). Project-based learning provides an authentic environment in which students can become more skillful at learning and solving problems through collaboration.

Similarities between project-based learning and process writing

Process writing finds a parallel in project-based learning. Many teachers are familiar with presenting writing as a process and are aware that the steps of process writing—brainstorming, organizing ideas, developing a draft, obtaining feedback, revising, and publishing—are similar to those required in many other creative projects. Often reports or computer-aided presentations created through process writing constitute a project's final product.

Additional support for project-based learning can be found in the various reports on student content standards developed by organizations such as the National Academy of Sciences and the National Council of Teachers of Mathematics. These reports stress the importance of engaging students in authentic and multidisciplinary tasks, which are hallmarks of many project-based learning environments.

Benefits of Project-Based Learning

A search of the literature identifies thousands of articles on classroom projects. Most of these reports can be considered testimonials, in which teachers tell how they use projects in their teaching and how successful they feel it has been. Benefits attributed to project-based learning include:

Teacher-reported benefits of project-based learning

- **increased motivation:** Accounts of projects often report that students willingly devote extra time or effort to the project or that previously hard-to-reach students begin to participate in class. Teachers often report improvements in attendance and decreases in tardiness. Students often report that projects are more fun and more engaging than other components of the curriculum.

- ***increased problem-solving ability:*** Research on how to improve students' higher-order cognitive skills emphasizes the need for students to engage in problem-solving tasks and for teachers to provide specific instruction on how to attack and solve problems (Moursund 1995; Perkins 1992). Many articles describe project-based learning environments, in which students actively and successfully pose and solve complex problems.
- ***improved research skills:*** Most projects require students to move beyond easily available printed information sources such as textbooks, encyclopedias, and dictionaries. Information technologies offer ready access to excellent additional sources of information on computer disk, CD-ROM, and the Internet. Project-based learning also encourages students to become independent researchers, which is in keeping with the American Library Association's call for "information literacy" as a fundamental goal. The ALA defines information literacy as the abilities to recognize a need for information, to identify and find the needed information, to evaluate and organize the information, and to use it effectively to address the problem or issue at hand (Breivik and Senn 1994). Project-based learning can provide an authentic context that motivates students to increase their levels of information literacy.
- ***increased collaboration:*** Many projects entail group work, which requires students to develop and practice communication skills (Johnson and Johnson 1989). Through collaborative projects, students gain experience in teaching their peers, evaluating the work of others, sharing information online, and learning cooperatively. Current cognitive theories suggest that learning is a social phenomenon and that students will learn more in a collaborative environment (Wiburg 1994).
- ***increased resource-management skills:*** Part of becoming an independent learner is taking responsibility for completing complex tasks. Well-implemented project-based learning gives students instruction and practice in organizing projects and in allocating time, equipment, and other resources to complete tasks on schedule.

Project-Based Learning in the Classroom: Instructional Goals, Implementation, and Student Assessment

Project design:
set clear academic goals

Instructional Goals and Design of Projects

The design of a learning project begins with the formulation of clear academic goals. Some of these will be specific to the subjects under study—understanding the structural strength of geometric shapes, the history of the Civil Rights movement, or the effects of mass and acceleration on moving bodies. Another set of goals has to do with the process of learning—acquiring the knowledge, skills, and abilities to pursue complex tasks over time; work in a team; or locate, retrieve, organize, and apply information gleaned from multiple sources.

Once the learning goals are established, teachers (or teachers and students working together) can begin to design and schedule activities. One time-tested set of project planning guidelines, developed by Al Rogers of the Global SchoolNet Foundation, comes out of educational telecommunications, where teachers have been developing multisite projects for many years (Rogers et al. 1990).

Among other characteristics, successful projects

- **have specific goals, tasks, and outcomes aligned with instructional objectives;**
- **have specific beginning and ending dates and intermediate deadlines;**
- **provide examples of the kinds of writing or data collection that students will submit.**

Teachers and students need to carefully inventory and allocate resources—time, prerequisite knowledge and skills, technology, and information sources. This is particularly true when activities depend on sophisticated or scarce technology or on collaboration with other classrooms or subject-matter experts from the community. Written or unwritten rules governing the project may limit the kinds of resources that students may use. For example, there may be rules on how much help is allowed from parents and others.

As the student or team begins to understand the demands of the project and determines the resources that are available, the next step is to develop a plan of action. What tasks need to be accomplished? What resources are needed to accomplish these tasks? Can some of the tasks be done simultaneously? Which must be completed before others can be started? In a large project, it is helpful to have milestones—specific tasks to be completed by specific times. What are the criteria to be used to measure whether a milestone has been successfully reached?

A project should be carefully crafted from the beginning to specify its learning goals and expected outcomes, the resources available as well as the resource limitations, and a plan of action. These activities take place simultaneously, cyclically, and repeatedly throughout a project. The process of working on any one of these steps produces information and insights that may lead one to rethink another step.

Project design:
develop a plan of action

A common pitfall for both teachers and students is failing to allocate enough resources (especially time) to provide for unforeseen difficulties. What happens if a team member is ill? What happens if a particular task proves to be more difficult than anticipated? What happens if a needed piece of equipment is out for repair? A robust plan includes a “contingency fund” allocation of time and other resources.

Project design:
allow for contingencies

It may be useful for the teacher to summarize project planning in a table, much like that below, which lays out the tasks and subtasks, resources needed, timelines for undertaking each job, and milestones that indicate the task’s completion:

	Description	Resources	Timeline	Milestones
Task 1				
Subtask 1.1				
Subtask 1.2				
Task 2, etc.				

A similar table can be provided to students as a prompt and guide for doing their own planning.

Feedback and Assessment

Conventional instruction often calls upon students to carry out relatively small tasks (textbook exercises, short essays, quizzes) and then to receive answers, feedback, and a grade from the teacher. As noted above, project-based learning often involves real-world, authentic activities that may be partially guided by an individual's strengths and interests.

Project design: establish appropriate evaluation of student work

As a result, not all of the students involved in a project are learning the same things at the same time. This can make the teacher's task of assessing student progress and providing feedback more complex than it is in other forms of instruction.

Characteristics of authentic assessment

Methods of *authentic assessment* are well suited to the evaluation of such projects. Authentic assessment requires students to apply and demonstrate their knowledge by carrying out real-world tasks and creating actual products. Examples include retrieving information from multiple sources and integrating it into well-reasoned arguments to support an idea; creating a work of art or music to enhance a presentation; and designing and carrying out an experiment to test a hypothesis.

Authentic assessment involves a careful examination of student products and performances. Increasingly, teachers are helping students learn to critique their own and one another's work.

For instance, Vito Dipinto and Sandra Turner (1995) describe a three-part procedure in which seventh-grade students are taught how to evaluate their own hypermedia reports. Each student researches a mammal as part of the science curriculum and presents his or her findings in the form of a HyperCard stack.

The teacher first models how to use an evaluation rubric and what to look for in a successful product. A few students volunteer to have their stacks evaluated, and the class clusters around a single machine while the teacher critiques a stack. Evaluation includes the extent and accuracy of its information, the mechanics of the writing, and the design of the presentation.

Students then evaluate one another's work using a peer assessment feedback form. Finally, students write a short essay, guided by a set of questions, in which they reflect on what and how they learned during the project. The teacher's modeling, the assessment feedback form, and the discussion about the evaluation rubric provide the necessary scaffolding for students to complete their assessment tasks successfully.

A number of states and individual school districts now use portfolio assessment, in which the output of projects and other student work becomes part of an individual's record. Technology has helped to facilitate the storage and evaluation of student products.

Moersch and Fisher (1995) describe a computer application they designed to help both the teacher and the student showcase examples of student work. The software contains scoring rubrics in which the teacher can check off skills and levels of mastery. The multimedia features of the computer are used to capture digital information (text, sound, graphics, video) that represents student work from both non-computer projects and computer-based activities.

Technology-assisted
authentic assessment

Authentic assessment is an important component of the continuing search for evaluation methods that are valid, reliable, and fair (Baker 1993) and that move the curriculum and pedagogy in directions that will improve education.

Robert Rothman's 1995 book, *Measuring Up*, discusses pros and cons of authentic assessment, summarizes the research literature, and gives a number of examples of major implementation efforts. Assessment is addressed in more detail in another report in this series.

Information Technologies, Hardware and Software: Their Use in Project-Based Learning

Information Technologies in Project-Based Learning

Projects are commonplace in formal technology classes, in which students develop computer programs, databases, multimedia, or other products on the way to mastering the equipment and software. However, information technologies can also facilitate project-based learning in science, language arts, fine arts, social studies, and other subject-matter disciplines.

For example:

Project-based learning in specific academic disciplines

- **A class of third graders is studying the modern Civil Rights movement in the United States. One pair of girls uses multimedia authoring software to create a simulated TV newscast from Montgomery, Alabama, on the day Martin Luther King Jr. is released from jail in Birmingham. In preparing the “newscast,” they study King’s speeches, develop a story board, and write, edit, rehearse, and perform their scripts. The authoring software allows them to include a video clip of the actual speech King gave that day in 1963. Other students in the same class approach the problem in a different manner. They use desktop publishing software to produce a simulated *Montgomery Advertiser* for December 2, 1955, the morning after the arrest of Rosa Parks that triggered a major bus boycott (Nix 1995).**
- **Sixth graders with learning disabilities use the KIDLINK list server to collect sunrise/sunset observations from around the world—almost pole to pole—on the day of the winter solstice. Although the students are in Wisconsin, they receive regular assistance from a professional meteorologist in Maryland via the World Wide Web. Students communicate with participating sites by email, locate sites by latitude and longitude, compute daylight hours, and create a database of sites and daylight. Following the data collection and analysis, students study the implications of their findings, such as the scientific explanation for why we have seasons. They pose questions and seek answers on such topics as the effects of living in constant daylight or darkness for part of the year (SIG/Tel 1995).**

- **Students at several elementary and secondary schools in Idaho use CD-ROMs, video and audio production gear, power tools, and robots to carry out a variety of assignments, from publishing a class newsletter to building a model car that can protect a raw egg in a high-speed collision. One instructional goal of these projects is to help students understand the importance of letting the problems dictate which kind of equipment to use. Students work together in small teams. The teacher is available to offer suggestions and explain how the equipment works, but avoids prescribing solutions (Graumann 1993).**
- **Nebraska high school students “shadow” adults on the job. The students employ a variety of information technologies to take notes, make recordings, and take pictures. Using hypermedia they incorporate these materials into multimedia research reports on careers. The nine-week project begins with students learning interviewing techniques and computer-based approaches to business communications (Hoffman 1995).**
- **A three-period course in an Oregon high school integrates the subjects of United States history and literature with information technology. The coursework involves the creation of both group and individual hypermedia projects that integrate knowledge from the three areas. Teams of students work together to study the Great Depression in the United States, dividing the research into such areas as transportation, family life, clothing, music, and food. The students make use of a wide range of information resources and information technology tools. They learn from one another and help their teachers learn. They present their finished products to the entire class (Smith 1993).**

As these examples show, information technologies can affect both the nature and content of project-based learning. In some cases, technology makes it easier to do basic tasks, as when students use a word processor to revise text during the writing process.

In other cases, technology extends the scope of a project in ways that would otherwise be impossible, as when students gather simultaneous data from remote sites via telecommunications, or publish their results in the form of videotape or a World Wide Web page.

Hardware and Software Considerations

Technology-dependent projects require hardware and software that are readily available and properly configured. In addition, both teachers and students must have sufficient knowledge and skills to take advantage of these tools. Project planners must allot time for this basic training or must select activities that help participants acquire new technology skills as the project proceeds. If teachers expect to spend part of a project teaching information technology skills, they may need to limit the scope of other content.

Teachers sometimes feel that they cannot use information technologies in project-based learning because their schools or classrooms lack appropriate modern equipment, but many teachers have overcome these difficulties.

Non-computer-based
technology in the classroom

Projects can often be designed for a one-computer classroom. Multimedia writer Fred D'Ignazio has pointed out that many technology tools are already available in schools (D'Ignazio 1995-1996). Camcorders, still cameras, VCRs, television sets, and tape recorders can often be borrowed or obtained as gifts. These devices can support multimedia project-based activities that do not require computers.

These common tools are often familiar to teachers and students from home use and may require little initial training. Photos and recordings made on these simple tools can later be incorporated or edited into computer-based multimedia presentations by adding such devices as digitizing adapters and scanners. Digital versions of cameras and recorders can provide direct input to computer applications.

Numerous specialized computer products can also support project-based learning. Hand-held digital appliances can help students perform specialized data collection and analysis tasks for a project, especially when a field-based location is involved. Multimedia authoring programs, available for most computer platforms, allow teachers and students to develop complex and visually attractive computer presentations and databases even if they do not have advanced programming skills.

With just a brief introduction to the software, students can undertake projects that are both challenging and intrinsically rewarding. When they want to use the more advanced features of the software, they can learn on their own, from fellow students, or with a modest amount of help from the teacher.

Ease of software use
in the classroom

Electronic information-gathering tools have become more accessible in recent years. Searching for Internet-based information formerly required mastery of arcane file transfer commands. The World Wide Web has made this activity technically easy in classrooms that enjoy Internet access.

CD-ROM drives, which typically used to be housed at special workstations in the library, are standard equipment on computers. The World Wide Web and CD-ROM technologies allow students to find original source material from the past and present—the latest photographs from the Hubble Space Telescope, original drafts of the Gettysburg Address in Lincoln’s handwriting, current research reports, and audio clips of T. S. Eliot reading his own poetry aloud.

The primary challenge for teachers in technology-based projects is not to acquire more information. Instead, the challenge lies in applying their training and wisdom to help students search through, organize, and make sense of the vast amount of information already available. An important aspect of this challenge centers on helping students focus on the subjects they are learning rather than on the bells and whistles of the technology.

Teachers’ challenge:
applying their wisdom to
help students locate and analyze
information

Professional Development Needs for Implementing Technologically Enhanced Project-Based Learning

Some teachers remain uncomfortable with having their students work with sophisticated technology in multidisciplinary projects that extend beyond the teacher's area of expertise. They feel they need additional professional development to take such a step.

The lack of adequate professional development has been described as possibly the single greatest obstacle to teachers making use of educational technology (Office of Technology Assessment 1995).

Some professional development challenges include

- **learning how to help students function productively in a project-based learning environment;**
- **learning more about how to find or develop good projects that fit one's instructional objectives and the available equipment resources;**
- **learning how to provide effective feedback to students, both as they work on projects and after they complete them;**
- **learning how to work with students in a "high-tech" project-based learning environment in which many of the students know more about the technology than the teacher does.**

Professional development needs in order to apply technology for classroom uses

These changes require commitment from teachers and support from the school over a period of time. Means and Olson (1995) found that even after extensive professional development, many teachers continue to use traditional didactic forms of instruction, primarily because they are reluctant to add to the multiple demands they already shoulder. Breivik and Senn (1994) reported that for many of their correspondents, the transition from expository to resource-based learning took from three to five years.

There has been a great deal of research on professional development and its role as a change agent in education. It is one of the major keys to school renewal and school improvement.

Transition to resource-based learning: three to five years

Another paper in this report focuses specifically on professional development for information technologies in education. Perhaps the single most relevant idea for this discussion is that a new paradigm is taking shape in which teachers view themselves as lifelong learners.

Final Remarks

Project-based learning is a well-established component of our educational system. It is an excellent vehicle for helping students learn to carry out authentic, multidisciplinary tasks in which they budget their time, make effective use of limited resources, and work with other people.

Information technologies bring new opportunities and challenges to project-based learning. There is a constant expansion of computer facilities and connectivity in schools.

In addition, many schools and school districts are placing considerable emphasis on technology-oriented professional development. This combination of improving facilities and increasing teacher knowledge supports the wider use of information technologies in project-based learning.

“Project-Based Learning and Information Technologies” is one of several papers included in *Connecting the Bits, A reference for using technology in teaching and learning in K–12 schools*, issued by the National Foundation for the Improvement of Education in 2000, and available at www.nfie.org.

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TERC Communications. *Hands On!* Cambridge, Mass.

TERC has developed and coordinated numerous technology-based learning projects over three decades. *Hands On!* is TERC's semiannual newsletter of hands-on math and science learning. It is also available online at <http://www.hub.terc.edu/gn/hub/owner/terc/hands-on.html>.

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First of a two-part "Research Windows" column discussing recent research on the effects of educational technology on improving problem solving.

