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THE GEORGE LUCAS EDUCATIONAL FOUNDATION

BOOK EXCERPT

TEACHING FOR MEANINGFUL LEARNING

A Review of Research on Inquiry-Based and Cooperative Learning

By

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and

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Introduction

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Our Foundation began in 1991 with an ambitious mission: to demonstrate how innovative learning environments in classrooms, supported by powerful new technologies, could revolutionize learning. As an organization founded by George Lucas, we believed that the same benefits of technology that were transforming business, health care, manufacturing, entertainment, and other sectors could be applied in education. And this was in the days before the Internet.

Nearly two decades later, the world has moved ahead in dramatic ways, but our schools remain caught in a web of educational thinking and systems that originated a century ago. The instructional model of the teacher and the textbook as the primary sources of knowledge, conveyed through lecturing, discussion, and reading, has proven astonishingly persistent.

Fortunately, this “dominant paradigm” is showing signs of wear. In our work of telling stories of innovative learning, we see many more examples of teachers, principals, and district administrators implementing new forms of project-based curricula and performance-based assessment. In these classrooms, students are working in teams to address open-ended and complex questions, such as “What is the air and water quality in your community?” “How would you design a school of the future? Or a hybrid car?” These students are sifting information from many sources and producing projects to present their knowledge, using computers and the Internet throughout. Their teachers are embracing their new role as learning coach and manager, rather than as exclusive instructor.

As a Foundation, we have understood the critical importance of developing a research basis for these innovations. In order for the exemplars we have profiled to take root in more places, their effectiveness must be demonstrated in educational research. Importantly, policymakers investing funds to bring these innovations to scale must be able to base their policies on documented results. These beliefs led to our support for research published in the book, *Powerful Learning: What We Know About Teaching for Understanding* (Jossey-Bass, 2008), from which this article is excerpted.

On behalf of our Foundation, I express our appreciation to the authors of the book: Dr. Brigid Barron and Dr. Linda Darling-Hammond of Stanford University; Dean P. David Pearson, Dr. Alan Schoenfeld, Dr. Timothy Zimmerman, Dr. Gina Cervetti, and Jennifer Tilson at the University of California, Berkeley; and Dr. Elizabeth Stage at the Lawrence Hall of Science. Dr. Darling-Hammond also served as editor for the volume.

This impressive group of leaders in educational research has taken an important step forward for the field. Their review of the literature on project-based learning, cooperative learning, and instructional strategies in literacy, mathematics, and science summarizes what is known and what new research is needed. While they point to studies of the effectiveness of these strategies, they also issue this important caveat: effectiveness relies heavily on the readiness and quality of teachers implementing them. Their book includes vignettes of schools and programs illustrating these practices, with links to films and articles on our Edutopia website and other web resources.

We also thank our partners at Jossey-Bass, editors Kate Gagnon and Lesley Iwa, for bringing this book to publication.

We hope that *Powerful Learning* provokes new thinking about the investments needed to create more powerful twenty-first century schools and school systems.

Teaching for Meaningful Learning:

A Review of Research on Inquiry-Based and Cooperative Learning

By Dr. Brigid Barron and Dr. Linda Darling-Hammond, Stanford University

"Decades of research illustrate the benefits of inquiry-based and cooperative learning to help students develop the knowledge and skills necessary to be successful in a rapidly changing world."

Since "A Nation at Risk" was published a quarter-century ago, mountains of reports have been written about the need for more powerful teaching and learning focused on the demands of life and work in the twenty-first century. Consider this: In 1900, 95 percent of all jobs were low skilled and required only that employees could follow basic procedures designed by others. In 2008, many jobs require specialized knowledge and skills. Today's employees must be able to communicate and collaborate, research ideas, and collect, synthesize, and analyze information. They need to develop new products and to be able to apply different areas of knowledge to new problems and challenges.

In short, the nature of work has changed—and continues to do so. According to the U.S. Department of Labor, the average worker will hold more than 10 jobs before the age of 40. The top 10 "in demand" jobs projected for 2010 did not exist in 2004.

The changing workforce and the need for so-called twenty-first-century skills have changed what it means to provide every child with an effective education that prepares them for a full and productive life. It's no longer enough to simply transmit information that students memorize and store for future use. Education today must focus on helping students learn how to learn, so they can manage the demands of changing information, technologies, jobs, and social conditions.

How do we prepare our students for these twenty-first-century skills?

Traditional academic approaches—narrow tasks that emphasize memorization or the application of simple algorithms—won't develop students who are critical thinkers or students who can write and speak effectively (Bransford, Brown, & Cocking, 1999; Bransford & Donovan, 2005). To develop these higher-order skills, students need to take part in complex, meaningful projects that require sustained engagement, collaboration, research, management of resources, and the development of an ambitious performance or product.

In fact, a growing body of research suggests that students learn more deeply and perform better on complex tasks if they have the opportunity to engage in more "authentic" learning—projects and activities that require them to employ subject knowledge to solve real-world problems. Studies have shown a positive impact on learning when students participate in lessons that require them to construct and organize knowledge, consider alternatives, engage in detailed research, inquiry, writing, and analysis, and to communicate effectively to audiences (Newmann, 1996). For example, a study of more than 2,100 students in 23 schools found significantly higher achievement on intellectually challenging performance tasks for students who experienced this kind of "authentic pedagogy" (Newmann, Marks, & Gamoran, 1995). Indeed, use of these practices resulted in stronger performance regardless of race, gender, or prior achievement.

The research highlighting the benefits of authentic learning, together with a growing interest in providing students with more engaging, thought-provoking learning opportunities, has prompted teachers at all grade levels to experiment with incorporating inquiry-based learning into their curriculum. But interest alone does not make for effective implementation of new models. Indeed, "learning by doing" has a somewhat checkered track record, in part because teachers often lack the information, support, and tools necessary to fully integrate and support this alternative approach to teaching and learning.

This chapter seeks to expand our knowledge of the benefits of inquiry-based learning, as well as to deepen our understanding of the components of an effective inquiry-based lesson or unit. We'll explore three approaches to inquiry-based learning: project-based learning, problem-based learning, and learning by design, highlighting key research and unpacking important elements of each approach.

A Pathway to Deeper Knowledge

Project-based learning involves completing complex tasks that typically result in a realistic product, event, or presentation to an audience. Thomas (2000) identifies five key components of effective project-based learning. It is: central to the curriculum, organized around driving questions that lead students to encounter central concepts or principles, focused on a constructive investigation that involves inquiry and knowledge building, student-driven (students are responsible for designing and managing their work), and authentic, focusing on problems that occur in the real world and that people care about.

Generally, research on project-based learning (PBL) has found that students who engage in this approach benefit from gains in factual learning that are equivalent or superior to those of students who engage in traditional forms of instruction (Thomas, 2000). The goals of PBL are broader, however, than simply the development of content knowledge. This

Assessment Matters

How we assess students—both formatively and summatively—has enormous implications for what we teach and how effectively we teach it. In collaborative and inquiry approaches to learning, three components of instruction—assessments, classroom activities, and curriculum—are interdependent components of a system that can be designed to promote flexible knowledge development.

Assessment systems that support cooperative and inquiry approaches to learning share three key characteristics:

- Intellectually ambitious performance assessments that enable students to learn and apply desired concepts and skills in authentic and disciplined ways.
- Evaluation tools, such as assignment guidelines and rubrics, which define what constitutes good work and effective collaboration.
- Formative assessments to guide feedback to students and to shape their instructional decisions throughout a unit.

As teachers of all grade levels recognize, the types of assessments used play a significant role in shaping the work students are asked to undertake. Research suggests that inquiry-based learning demands thoughtfully structured performance assessments, both to define the tasks students are engaged in and to properly evaluate what has been learned. Good performance assessments are complex intellectual, physical, and social challenges. They stretch students' thinking and planning abilities, while also allowing student aptitudes and interests to serve as a springboard for developing competence.

Through these tasks, students are not only required to demonstrate their competencies, but the tasks themselves require use of critical skills, including planning, setting priorities, organizing individual and group efforts, exerting discipline, determining how to communicate effectively with an audience, and understanding ideas well enough to answer the questions of others.

There are many ways in which performance assessments contribute to learning. For example, exhibitions, projects, and portfolios provide multiple occasions for review and revision toward a polished performance. These opportunities help students examine both how they learn and how to improve their performance. Students are often expected to present their work to an audience, such as groups of faculty, visitors, parents, or other students, to ensure that their mastery is genuine. These public presentations signal to students that their work is valued and reinforce the significance of their tasks in a real-world context.

In the table below, we summarize the types of assessment that can be used in inquiry-based lessons. As the table shows, assessment strategies can include rubrics that are applied to artifacts, whole class discussions, midcourse design reviews, performance assessments, and new-transfer problems. The most effective inquiry-based approaches use a combination of informal ongoing formative assessment and project rubrics that communicate high standards and help teachers make judgments about the multiple dimensions of project work. For rubrics to be useful, they must include scoring guides that specify criteria, ideally written for both teachers and students.

An important aspect of ongoing assessment is the development of students' capacity to assess their own work, so that they internalize standards and become aware of and thoughtful about their own learning. The power of these approaches has been illustrated in many studies, including a comparison group study that evaluated the impact of self-assessment on student learning in twelve inquiry-based middle school science classrooms. The experimental groups spent half of their time in discussion structured to promote self- and peer assessment of cognitive goals and processes, while the control group used this time for general discussion of the concept.

The study found that students involved in self-assessment showed significantly larger gains on both a conceptual physics test and on project scores, and that students with low pretest scores showed the largest gain on all of the outcome measures. Another analysis of formal and informal self-evaluation processes concluded that an integrated practice of self-assessment led students to assume greater responsibility for their own learning.

Well-crafted performance assessments can also lead to better teaching. For example, teachers who have been involved in scoring performance assessments with other colleagues and discussing their students' work have reported becoming more problem-oriented and more diagnostic in their teaching.

Two final notes: For assessments to serve the critical functions detailed above, they must be grounded in a conception of learning as developmental and in a belief that all students will learn from experience and feedback, rather than being constrained by innate ability. It is also important to remember that the most effective performance assessments are part of a related set of practices that include the integration of assessment and instruction, systematic use of iterative cycles of reflection and action, and ongoing opportunity for students to improve their work.

Type of Assessment	Form of Feedback
Rubrics	Detailed specifications of students' work products, with levels of progress defined. Students should understand the rubric before beginning the work and should revisit it throughout a project.
Solution Reviews	A public opportunity for students to show work in progress and obtain feedback from peers, teachers, or other community members.
Whole Class Discussion	Structured classroom discussions that provide a venue for the vetting of ideas and explanations and surface misconceptions that can be addressed mid-project.
Performance Assessments	Individual or small-group projects, usually of short duration, that enable teachers to assess students' ability to apply acquired knowledge in a new context.
Written Journals	Students maintain an ongoing record of experiences, reflections, and problem-solving throughout a project.
Portfolios	Students compile a collection of their work over time, usually highlighting progress and including personal reflection.
Weekly Reports	Students create weekly written responses to a set of simple questions throughout the duration of a project.
Self-Assessment	Students evaluate their own work according to predefined criteria, often using such tools, such as a rubric or focus questions.

approach aims to take learning one step further by enabling students to *transfer* their learning to new kinds of situations and problems and to use knowledge more proficiently in performance situations.

Some examples illustrate this point.

Shepherd (1998) studied the results of a unit in which a group of fourth and fifth graders completed a nine-week project to define and find solutions related to housing shortages in several countries. In comparison to the control group, the students engaged in project-based learning demonstrated a significant increase in scores on a critical-thinking test, as well as increased confidence in their learning.

A more ambitious, longitudinal comparative study by Boaler (1997, 1998) followed students over three years in two British schools that were comparable with respect to students' prior achievement and socioeconomic status, but that used either a traditional curriculum or a project-based curriculum. The traditional school featured whole teacher-directed class instruction organized around texts, workbooks, and frequent tests in tracked classrooms. Instruction in the other school used open-ended projects in heterogeneous classrooms. Using a pre- and post-test design, the study found that although students had comparable learning gains when tested on basic mathematics procedures, those who had participated in the project-based curriculum did better on conceptual problems presented in the National Exam. Significantly more students in the project-based school passed the National Exam in year three of the study than those in the traditional school. Boaler noted that, although students in the traditional school "thought that mathematical success rested on being able to remember and use rules," the PBL students had developed a more flexible, useful kind of mathematical knowledge that engaged them in "exploration and thought" (Boaler, 1997, p. 63).

A third study, designed to assess the impact of the development of multimedia projects on student learning, showed similar gains. In this example, researchers created a performance task in which students participating in the Challenge 2000 Multimedia Project and a comparison group developed a brochure informing school officials about problems faced by homeless students (Penuel, Means, & Simkins, 2000). The students in the multimedia program earned higher scores than the comparison group on content mastery, sensitivity to audience, and coherent design. They performed equally well on standardized test scores of basic skills.

Other short-term, comparative studies of traditional vs. project-based approaches have demonstrated several benefits from projects, such as an increase in the ability to define problems (Gallagher, Stepien, & Rosenthal, 1992), growth in their ability to support their reasoning with clear arguments (Stepien, Gallagher, & Workman, 1993), and enhanced ability to plan a project after working on an analogous problem-based challenge (Moore, Sherwood, Bateman, Bransford, & Goldman, 1996). Additional studies have documented positive changes for teachers and students in motivation, attitude toward learning, and skills, including work habits, critical thinking skills, and problem-solving abilities (see, e.g. Bartscher, Gould, & Nutter, 1995; Peck, Peck, Sentz, & Zasa, 1998; Tretten & Zachariou, 1995). Interestingly, students who may struggle in traditional instructional settings have often been found to excel when they have the opportunity to work in a PBL context, which better matches their learning style or preference for collaboration and activity type (see, e.g., Boaler, 1997; Meyer, Turner, & Spencer, 1997; Rosenfeld & Rosenfeld, 1998).

"Students who may struggle in traditional instructional settings have often been found to excel when they work in a PBL context."

Students as Problem-Solvers

Problem-based learning approaches are a close cousin of project-based learning. Lessons typically involve a specific type of activity focused on using reasoning and resources to solve a problem.

In problem-based learning, students work in small groups to investigate meaningful problems, identify what they need to learn in order to solve a problem, and generate strategies for solution (Barrows, 1996; Hmelo-Silver, 2004). They also implement these strategies, evaluate their results, and continue to generate new strategies as needed until they have solved the problem. The problems are realistic and have multiple solutions and methods for reaching them, rather than a single "right" approach.

In all problem-based approaches, students take an active role in building their knowledge, while the teacher's role is to make thinking visible, guide the group process and participation, and to ask questions to solicit reflections. In short, the goal for teachers is to model good reasoning strategies and to support the students to take on these roles themselves. Teachers also offer instruction in more traditional ways, such as lectures and explanations that are crafted and timed to support inquiry.

Much of the research into problem-based learning is associated with medical education, where this approach is widely used. For example, physicians-in-training are typically presented with a patient profile, including the patient's history and symptoms. Using this information, a small group of medical students must generate a diagnosis and then conduct research and perform diagnostic tests in order to identify possible causes of the pain or illness. The instructor typically plays a coaching role throughout the process. Meta-analyses of studies have found that medical students who are enrolled in problem-based curricula score higher on clinical problem-solving measures and on actual ratings of clinical performance (Vernon & Blake, 1993; Albanese & Mitchell, 1993) than peers who are not enrolled in such programs. Similar problem- or case-based approaches have been used in business, law, and teacher education to help students learn to analyze complex, multifaceted situations and to develop knowledge to guide decisionmaking (see, e.g. Lundeberg, Levin, & Harrington, 1999; Savery & Duffy, 1996; Williams, 1992).

For example, research has found that the use of cases in teacher education can help prospective teachers learn to apply theory and practical knowledge to specific school contexts and think through and resolve classroom dilemmas more productively. Through the use of case methods in which they analyze their practice and its outcomes —as well as the practice of others—teachers grow more capable of framing problems, drawing lessons

Implementing Project-Based Learning Districtwide

Robert J. Van Maren, superintendent of the Bonner Springs/Edwardsville School District near Kansas City, Kansas, believes "it's essential that learning not only be fun, but also be something that teachers and kids can get passionate about.

"I've never seen anyone be passionate about testing," adds Van Maren, "but as a result of No Child Left Behind and other like initiatives, that's what we've been forced to offer."

To change the paradigm, Van Maren championed a recent effort to bring the project-based Expeditionary Learning Schools (ELS) Outward Bound model—a type of learning that has been very successful in other schools and districts—to his own school district. In this model, the focus is on learning "expeditions"—long-term student investigations that, though keyed to state and federal standards, are designed to nurture a strong affinity for dynamic learning and a curiosity about the world beyond the classroom. In ELS schools, the focus is on learning by doing, rather than the more passive traditional classroom experience.

As a result of Van Maren's efforts, Kansas City's Ewing Marion Kauffman Foundation awarded five-year, $150,000 grants to four of his schools—three elementary schools and one middle school—to support their transformation into Expeditionary Learning Schools. That brought the total number of ELS schools in the Kansas City area to eleven, giving the region the opportunity to become the flagship of the movement.

Van Maren believes Expeditionary Learning is where their schools are headed—and that they'll get there without compromising national and state standards in the process.

"I'm an old science teacher, and I know that kids learn by doing, not by sitting there doing worksheets or practice tests," he says. "This grant allows us to use the best pedagogy available to teach using an investigative style, so kids can discover the linkages between what they're learning—not just math for math's sake, or science for science's sake. We believe that the test scores will take care of themselves."

By test scores, or almost any account, ELS has a successful track record in education reform. After just six years in operation, Congress hailed it as a national educational model and was signing up schools from coast to coast. In 2003, the Bill & Melinda Gates Foundation awarded it a five-year, $12.6 million grant to create twenty small college-preparatory high schools.

That track record was one reason the Kauffman Foundation chose to partner with ELS. Another was diversity.

"In Kansas City, we have a huge range of school settings—large, small, rural, urban, suburban, wealthy, not wealthy—so we looked hard to find an innovative program that could accommodate our needs," says Margo Quiriconi, the organization's director of research and policy. "Their model has been successfully implemented in almost every kind of school imaginable."

Getting Buy-In

This success is due in part to an ELS mandate regarding program buy-in: Before a school can apply, the school board must unanimously approve it, and 80 percent of school staff must agree on the proposal.

"Even though this is a school-based model, not a district-based model, we can't pick a school if we don't have support from the top down," says Corey Scholes, a former K–8 principal who is now the ELS representative working with the Bonner Springs schools. "Changing an entire school culture is really hard work. You just can't do it without the support of both administration and the teachers. The Bonner Springs school system showed an intense dedication to the model."

Joseph DiPinio, principal of grant recipient Robert E. Clark Middle School, was a staunch supporter from the beginning. "As part of the grant process, we visited Expeditionary Learning Schools around the country, and, in every instance, I walked away with the thought 'That's how I want my school to be,'" he says. "When you see something good for kids, you want to figure out a way to make that happen, but the costs for the professional development and the school design are so extensive. We wouldn't have been able to afford to do this comprehensively on our own."

MORE INFORMATION

For more information on the Expeditionary Learning Schools Outward Bound Model, go to elschool.org

Though excitement about the new venture is evident, Bonner Springs's superintendent acknowledges that the next five years will be challenging.

"Change is difficult, and it's always easier to just keep doing what you've always done," Van Maren says. "But we want different results. We want our kids to reach a new level of potential and be competitive with kids all over the world. Just as important, we want to bring the joy and passion back into the classroom. We want to create a learning experience that kids and teachers will never forget."

Adapted from Edutopia article, **"River Journeys and Life Without Bathing: Immersive Education,"** *by Laura Scholes (May 15, 2007).*

beyond their immediate setting, and reflecting upon their work from multiple perspectives. Cases have been found to be helpful in enabling teachers to take alternative perspectives, for example, to better understand and appreciate cultural diversity. For many teachers, writing cases about their own practice leads to a kind of "reflection-on-action" that results in professional learning and changes in practice (Darling-Hammond & Hammerness, 2002).

Studies of the efficacy of problem-based learning suggest that it is comparable, though not always superior, to more traditional instruction in facilitating factual learning. This approach has been found to be better, though, in supporting flexible problem solving, application of knowledge, and hypothesis generation (for a meta-analysis, see Dochy, Segers, Van den Bossche, & Gijbels, 2003). Additional studies have demonstrated that students who participated in problem-based experiences are better able to generate accurate hypotheses and coherent explanations (Hmelo, 1998b; Schmidt et al., 1996) and to support their claims with well-reasoned arguments (Stepien et al., 1993). They also experience larger gains in conceptual understanding in science (Williams, Hemstreet, Liu, & Smith, 1998).

Learning Through Design

A third genre of instructional approaches is based on the premise that children learn deeply when they are asked to design and create an artifact that requires understanding and application of knowledge. Design-based lessons have several features that make them ideal for developing technical and subject matter knowledge (Newstetter, 2000). For example, design activity supports revisions and iterative activity as students create, assess, and redesign their work product. The complexity of the work often dictates the need for collaboration and specific roles for different students, providing them with the opportunity to become "experts" in a particular area. Finally, design projects require students to set constraints, generate ideas, create prototypes, and develop plans through storyboarding or other representational practices. These are all critical twenty-first century skills.

Design-based approaches can be found across many disciplines, including science, technology, art, engineering, and architecture. Competitions, such as the FIRST robotics competitions (www.usfirst.org) or the ThinkQuest competition (www.thinkquest.org) also stress design using technological tools and collaborative project work. In the ThinkQuest competition, for example, teams of students design and build Web sites on topics ranging from art, astronomy, and programming to foster care and mental health. Student teams are mentored by a teacher who gives general guidance throughout the design process, leaving the specific creative and technical work to the students. Teams receive and offer feedback during a peer review of the initial submissions, and then use this

Tomorrow's Engineers: Building a Competitive Robot

Every year, thousands of students meet to put their creations through their paces in a competition that involves a wide-range of twenty-first century skills: teamwork, problem solving, and perseverance, as well as imagination, creativity, professionalism, and maturity. The students, teachers, and mentors who participate in the First Robotics Competition (FRC) also have a whole lot of fun.

Started by engineer and inventor Dean Kamen, FIRST (For Inspiration and Recognition of Science and Technology) is all about inspiring and motivating students to become engaged in math, science, engineering, and technology. Each year, teams of students, teachers, and professional engineers respond to the FIRST challenge by designing and building a robot.

"To passively sit in a classroom is a nineteenth-century format," Kaman has said. "In this next century, you're going to have to be creative, or you're not going to make it."

Hands-On Science and Engineering

The regional and national competitions are the culmination of six intense weeks, during which students, working with high school teachers and professional engineers, design and build a remote-control robot that can complete specific tasks and maneuver through a specially designed course.

"Mentoring plays a big role in the process right from the start," says Lori Ragas, senior teams coordinator for FIRST. From the first brainstorming session to the last match at one of the regionals or the national competition, professional engineers work side-by-side with the high school students, explaining the functions of different parts, providing feedback on design options, and rolling up their sleeves to repair a faulty part or tinker with a design element.

For a team from Poudre High in Fort Collins, Colorado, the first week and a half after the design challenge is announced is devoted to what teacher and robotics coach Steve Sayers calls "pure strategy." Everyone—from the first-year participant to the veteran team member, from parents to professional engineers—puts forth design ideas. From those best ideas comes a basic design, which the team will spend the next five weeks refining, fabricating, and testing on a prototype of the actual competition course.

Although much of the work revolves around design and engineering, robotics coach Sayers, who was a chemical engineer before making the switch to teaching, is quick to point out that a successful team requires an eclectic mix of students with a variety of skills and interests.

"If a student wants to be on the team, the first questions I ask them are, 'What do you enjoy doing? What are you good at?'" says Sayers, adding that there's "something for everyone" on the Poudre High robotics team. Students interested in computers do the programming or computer-aided design and animation work. Those with an artistic flair design everything from team T-shirts to fliers to the look and feel of the robot itself. Writers create the design documentation. The list of responsibilities, says Sayers, goes on and on. And no one job, he is quick to add, is more important than any other.

In addition to providing hands-on science and engineering experience, the robotics program teaches students valuable lessons in cooperation and teamwork.

Respect. Cooperation. Learning to be a team player. These are just a few of the "life skills" students learn through the robotics program. They're skills, say team members and adult advisers alike, that students will carry with them—whether or not they decide to pursue a career in science or engineering.

MOREINFORMATION

Watch a video about Poudre High School's Robotics Team at **edutopia.org/pourdre-high-school-robotics**. *For more information on FRC and First Competitions, visit* **usfirst.org**

Adapted from Edutopia article, **"Building a Better Robot: A Robotics Competition Introduces Students to Engineering,"** *by Roberta Furger (December 3, 2001).*

information to revise their work. To date, more than 30,000 students have created more than 550 Web sites through this competition (www.thinkquest.org/library/).

There are relatively few studies that have used control-group designs to evaluate the impact of the learning-by-design model. In one such study, however, Hmelo, Holton, and Kolodner (2000) asked sixth-grade students to design a set of artificial lungs and build a partially working model of the respiratory system. They found that the design project led to better learning outcomes than the traditional approach to instruction. They also noted that the design students learned to view the respiratory system more systemically and understood more about the structures and functions of the system than the comparison group. Researchers also observed that design activities are particularly good for helping students develop understanding of complex systems, noting that the systems can be presented as a united whole whose structure is adapted to specific purposes (Perkins, 1986).

Echoing the findings of other classroom research, Hmelo and colleagues (2000) maintain, however, that design challenges need to be carefully planned. They contend that lessons should be designed to illuminate the functions of different elements of a system, and they stress the importance of providing dynamic feedback, allowing students to engage in multiple iterations of design, and giving adequate time to the entire system of classroom activities.

Much of the research on learning through design-based projects has been more naturalistic. These studies have either focused on a single design activity or on longer-term design experiments in which changes are made to the curriculum based on observations of learning processes and outcomes. For example, Fortus and colleagues (2004) conducted a study with 92 students that tracked their learning across three design-based science units that included designing a structure for extreme environments, designing environmentally friendly batteries, and designing safer cell phones. Each unit contained multiple design and learning cycles. The research team found that both higher- and lower-achieving students showed strong evidence of progress in learning the targeted science concepts, and that students were able to apply key concepts in their design work. They also noted a positive effect on motivation and sense of ownership over designs among both individuals and groups.

Findings

A growing body of research has shown the following:

- Students learn more deeply when they can apply classroom-gathered knowledge to real-world problems, and when they to take part in projects that require sustained engagement and collaboration.
- Active learning practices have a more significant impact on student performance than any other variable, including student background and prior achievement.
- Students are most successful when they are taught how to learn as well as what to learn.

Implementation Challenges

One of the most significant challenges to the successful implementation of inquiry approaches is the skills and knowledge of the teachers engaging in this alternative form of teaching and learning (Good & Brophy, 1986). When teachers don't fully understand the complexities of inquiry-based learning, they may simply think of this approach "unstructured," and may, as a result, fail to provide proper scaffolding, assessment, and redirection as projects unfold.

Research on inquiry-based learning has identified the risks and consequences when students lack prior experience in this approach or have insufficient support and modeling from teachers. For example, with respect to disciplinary understanding, students can have difficulty generating meaningful "driving questions" or evaluating their questions to determine if they are warranted by the investigation (Krajcik et al., 1998) or they may lack the background knowledge needed to make sense of the inquiry (Edelson, Gordon, & Pea, 1999). With respect to general academic skills, students may have difficulty developing logical arguments and evidence to support their claims (Krajcik et al., 1998). As for management of the work, students often find it hard to determine how to work together, manage their time and the complexity of the work, and sustain motivation in the face of setbacks or confusion (Achilles & Hoover, 1996; Edelson et al., 1999).

One of the principal challenges for teachers, then, is to learn how to juggle a host of new responsibilities and implementation issues—from carving out the time needed for extended inquiry to developing new classroom-management techniques. Teachers must also be able to design and support inquiry-based lessons that meet a variety of criteria, such as illuminating key subject matter concepts, balancing direct instruction with inquiry opportunities, scaffolding the learning of individual students through modeling and feedback, facilitating learning among multiple groups, and developing assessments to guide the learning process (Blumenfeld et al., 1991; Marx et al., 1994, 1997; Rosenfeld & Rosenfeld, 1998; Sage, 1996).

That's a tall order for even the most experienced teacher.

Successful inquiry-based approaches require careful planning and the development of strategies for collaboration, classroom interaction, and assessment. Some research has focused specifically on how to best support these new approaches to teaching and learning. For example, Puntambekar & Kolodner (2005) describe two studies designed to advance our understanding of the kinds of support students need to learn content in the context of design projects. They knew from earlier classroom research (Gertzman & Kolodner, 1996) that simply furnishing students with rich resources and an interesting problem (such as designing a household robot with arthropod features) was not enough. Students needed help understanding the problem, applying science knowledge, evaluating their designs, explaining failures, and engaging in revision. Students often neglected to use informational resources unless explicitly prompted.

To address these problems, the researchers introduced a design diary that was intended to explicitly introduce design process ideas and support four phases of design work: understanding the challenge, gathering information, generating a solution, and evaluating solutions. The goal of the curriculum was to help students learn about coastal erosion by designing a solution for a specific island off the coast of Georgia. To experiment with solutions, they had access to stream tables, as well as informational resources on videotape and the Internet. In addition to implementing the journal, they carried out

Intelligent Design: Immersing Students in Civic Education

The Build San Francisco Institute, a yearlong design program cosponsored by the Architectural Foundation of San Francisco (AFSF) and the San Francisco Unified School District (SFUSD), has as one of its core principles that subjects such as math, history, and writing have a broader context—they are essential tools for conceptualizing, understanding, sketching, and building relevant and compelling real-world projects.

"In a military academy, they don't teach trigonometry; they teach navigation," explains Build SF cofounder Richard Hannum. "Because you need trig for navigation, you learn it."

Offering accredited courses with titles such as Architectural Design and Urban Sociology, today's Build SF is the offshoot of an after-school and summer program launched 13 years ago. In 2004, as a part of the SFUSD's Secondary School Redesign Initiative, the program was expanded to an all-afternoon, five-day-a-week schedule; two of those days are devoted to working with mentors from some of San Francisco's leading architecture, interior-design, engineering, and contracting firms, along with city agencies involved in urban planning. The curriculum was designed to develop student interest in architecture-related fields and, more fundamentally, to immerse them in the process of meshing civic and business interests.

"It's not about building little architects," says Hannum. "Rather, we use architecture as a vehicle to give kids with no community context an insight into, and a voice in, the public process."

The ability to provide a bridge between education and business is why Janet Schulze, principal at San Francisco's John O'Connell High School of Technology, is a Build SF booster. The program, she says, is the fastest way to integrate academic skills into a real-world setting."

Schulze praised the effort San Francisco's design community dedicates to the program, particularly in terms of offering mentorships. "I'd love to see the medical and finance communities do something like it," she adds.

At Build SF's downtown studio, the decibel level is much higher than what would be acceptable in most high school classrooms. "This place does develop a certain hum," admits Alan Sandler, the foundation's executive director. "It's supposed to be like a busy office." AFSF programs director Will Fowler characterizes the ambiance as "the real sound of learning. It shocks and delights them that they are encouraged to talk to each other."

The use of the term studio rather than classroom is not accidental. According to Fowler, "We want the kids to understand that Build SF is more a design studio than it is a school."

Build SF's insistence on treating kids like adults takes some getting used to. Accustomed to dealing with hundreds of kids in a traditional high school setting, Boston-area refugee Brennan admits she was nervous in 2005 when she began instructing at Build SF. "We were trained never to leave kids alone," she adds. "When Will Fowler first told me to 'walk away,' it was difficult."

"There is only one rule," Fowler explains. "When Casey says, 'Listen up,' they have to listen up."

Rising to Challenges

Another central precept of Build SF is that participants be exposed to the unvarnished realities of life in the highly competitive and often-contentious world of design and architecture. One recent project involved creating a series of historically themed tiles for the city's newly redesigned Pier 14. The students had to first design the tiles and then present and "sell" their idea to the Port Commission—a process that took several iterations before the Commission was satisfied. The Build SF team had to master the complex process of tile production, from drawing, tracing, and painting to glazing and firing, as well as overseeing installation.

Some projects, such as the design and building of a bridge with sets of Lego blocks, are meant to get kids from different schools comfortable with one another. "Students tend to spend their entire school careers with the same kids from the same neighborhoods," the AFSF's Sandler says about the goal of opening up new vistas. "When they come here and leave their baggage behind, they're able to develop a different, adult, persona."

Comings and goings at the Build SF studio continue throughout the afternoon as students arrive from their morning high school classes, go to work on their various projects, or move on to their assigned mentorships. Some stay throughout the afternoon, and others depart for after-school activities at their respective high schools. This open-endedness might strike some critics as an easy way to ditch school. For the Build SF team, however, it is a critical part of the program. "Maybe for the first time in their school careers, kids have to be responsible for their own time," Sandler says. "Our key motto is 'Trust the kids'—treat them as professionals, and they will rise to the challenge each and every time."

Adapted from Edutopia article, **"Intelligent Design: Immersing Students in Civic Education,"** *by Richard Rapaport (March 2007).*

MORE INFORMATION

Watch a video on Build SF at **edutopia.org/learning-design**

For more information on the Build San Francisco Institute, go to **afsf.org/program_buildsf.htm** careful assessment of students' learning and observation of classroom interactions.

In this first study, the learning outcomes were disappointing, but instructive. For example, researchers noted that the teacher missed many opportunities to advance learning because she could not listen to all small group discussions and had decided not to have whole-group discussions. They also noted that the students needed more specific prompts for justifying design decisions.

In their second study, the researchers designed and implemented a broader system of tools and processes, which greatly improved the learning outcomes--notably, more structured diary prompts that asked for design rationales and explanations, and insertion of whole-class discussions at strategic moments. They also added new activity structures that required students to publicly defend designs earlier in the process. These processes of helping students keep track of and defend their thinking were very helpful.

In addition, the redundancy of learning opportunities afforded by the many forms of support was instrumental in helping students focus on learning concepts and connecting them with their design work.

Small-Group Learning

Much of the work involving inquiry-based learning involves students working in pairs or groups to solve a problem, complete a project, or design and build an artifact. Cooperative small-group learning, which Cohen (1994b) defines as "students working together in a group small enough that everyone can participate on a collective task that has been clearly assigned," has been the subject of hundreds of studies and several meta-analyses (Cohen, Kulik, & Kulik, 1982; Cook, Scruggs, Mastropieri, & Castro, 1985; Hartley, 1977; Johnson, Maruyama, Nelson, & Skon, 1981; Rohrbeck, Ginsburg-Block, Fantuzzo, & Miller, 2003). Overall, these analyses come to the same conclusion: there are significant learning benefits for students who work together on learning activities (Johnson & Johnson, 1981, 1989).

For example, in a comparison of four types of problems presented to individuals or cooperative teams, researchers found that teams outperformed individuals on all types and across all ages (Quin, Johnson, & Johnson, 1995). Problems varied in terms of how well defined they were (a single right answer versus open-ended projects, such as writing a story) and whether they were more or less reliant on language. Several experimental studies have shown that groups outperform individuals on learning tasks and that individuals who work in groups do better on later individual assessments as well (Barron, 2000a, b; 2003; O'Donnell & Dansereau, 1992).

Cooperative group work benefits students in social and behavioral areas as well, including improvement in student self-concept, social interaction, time on task, and positive feelings toward peers (Cohen et al., 1982; Cook et al., 1985; Hartley, 1977; Ginsburg-Block, Rohrbeck, & Fantuzzo, 2006; Johnson & Johnson, 1989). Ginsburg-Block and colleagues (2006) focused on the relationship between academic and nonacademic measures. They found that both social and self-concept measures were related to academic outcomes. Larger effects were found for classroom interventions that used same-gender grouping, interdependent group rewards, structured student roles, and individualized evaluation procedures. They

Expeditionary Learning

At King Middle School in Portland, Maine, celebrations with everyone from parents to community members are an important part of the learning process. King, like schools throughout the country, has adopted the Expeditionary Learning Outward Bound model of personalized, project-based learning. At least twice a year, students engage in extended interdisciplinary projects that culminate in a celebration of learning, during which they share their newfound knowledge and skills with the broader school community.

As with other Expeditionary Learning schools, King teachers incorporate a range of subjects into their projects – from art to science to language arts. The projects also include well-considered use of technology, due in no small part to the state of Maine's decision to provide all seventh and eighth graders with Apple iBook laptop computers.

Culminating events come in a number of forms: a performance of an original play, a presentation to younger students of a geology kit, or the production of a CD-ROM, book, or a video, all of which incorporate state curriculum standards. Projects at King have included an aquarium design judged by local architects, a CD narrative of Whitman's "O Captain! My Captain!" by students learning English, and *Voices of U.S.* (a book of immigrant stories), to name a few.

"The goal for us at King Middle School is to create opportunities for all kids to do representational work about their learning," says David Grant, King's technology teaching strategist. He works with both students and teachers to ensure that any video or computer or Web production furthers the curriculum. "It's in the making of things that kids actually do their learning," he says. Through their projects, adds Grant, students are able to demonstrate what they know. "That's always where we want to be working from—what they know and what they don't know. And working with these media allows that to happen."

Ann Brown, King's eighth-grade science teacher, likes the fact that video requires students to work in teams and to learn from each other. "That adds to the final product because the different angles produce different ways of approaching the same problem," she says. "You get pieces of the best ideas coming together, so the final product is that much better, and they're also learning from each other and thinking differently."

King put an end to tracking and special education "pullout" classes at about the same time it adopted the project approach to learning and began emphasizing the use of technology. Since then, test scores have shot up—a major accomplishment for a student population that is 60 percent low-income and 22 percent refugee and that comes to school speaking 28 different languages. Following years of below-average scores on the state achievement test, King students began outscoring the state average in six out of seven subjects in 1999, and they even moved into the top third in some subjects.

Adapted from Edutopia article, **"Laptops on Expedition: Embracing Expeditionary Learning,"** *by Diane Curtis (January 19, 2004).*

MOREINFORMATION

Watch a video on King Middle School's Expeditionary Learning Program at: edutopia.org/maine-video.
For more information on the Expeditionary Leaning Schools Outward Bound Model, go to elschool.org

also found that low-income students benefited more than high-income students and that urban students benefited more than suburban students. Racial and ethnic minority students benefited even more from cooperative group work than non-minority students, a finding repeated over several decades (see Slavin & Oickle, 1981).

Most recently, the focus of research has gone beyond the practical benefits of collaboration for individual learning to recognize the importance of helping children learn to collaborate as necessary preparation for all kinds of work. For example, the Science for All Americans, Project 2061 (American Association for the Advancement of Science, 1989) suggests that a core practice of scientific inquiry is collaborative work and that schools should prepare students for this kind of work through classroom activities that require joint efforts.

But effective cooperative learning can also be complex to implement. Research has identified at least three major challenges for cooperative learning in classrooms: developing norms and structures within groups that allow individuals to work together; developing tasks that support useful cooperative work; and developing discipline-appropriate strategies for discussion that support rich learning of content. Each challenge is discussed in the next section.

Productive Collaboration

A great deal of work has been done to specify the kinds of tasks, accountability structures, and roles that help students collaborate well. In Johnson and Johnson's summary (1999) of forty years of research on cooperative learning, they identify five "basic elements" of cooperation that have emerged as important across multiple models: positive interdependence, individual accountability, structures that promote face-to-face interaction, social skills, and group processing.

A range of activity structures has been developed to support group work, from cooperative-learning approaches where students are simply asked to help each other complete individually assigned traditional problem sets to approaches where students are expected to collectively define projects and generate a single product that reflects the continued work of the entire group. Many approaches fall between these two extremes. Some approaches assign children to management (e.g. Cohen, 1994a, 1994b), conversational (O'Donnell, 2006; King, 1990), or intellectual roles in the group (Palincsar & Herrenkohl, 1999, 2002; Cornelius & Herrenkohl, 2004; White & Frederiksen, 2005).

When designing cooperative group work, teachers should pay careful attention to various aspects of the work process and to the interaction among students. For example, Slavin (1991) argues, "it is not enough to simply tell students to work together. They must have a reason to take one another's achievement seriously." He developed a model that focuses on external motivators that reside outside the group, such as rewards and individual accountability established by the teacher. His meta-analysis found that group tasks with structures promoting individual accountability produce stronger learning outcomes (Slavin, 1996).

Cohen's review of research (1994b) on productive small groups focuses on internal group interaction around the task. She and her colleagues developed Complex Instruction, one of the best-known and well-researched approaches to cooperative small-group learning.

Complex Instruction uses carefully designed activities that require diverse talents and interdependence among group members. Teachers are encouraged to pay attention to unequal participation among group members, which often results from status differences among peers, and are given strategies that allow them to bolster the status of infrequent contributors (Cohen & Lotan, 1997). In addition, roles are assigned to support equal participation, such as recorder, reporter, materials manager, resource manager, communication facilitator, and harmonizer.

A major component of the approach is development of "group-worthy tasks" that are both sufficiently open-ended and multifaceted that they require and benefit from the participation of every member of the group. Tasks that require a variety of skills, such as research, analysis, visual representation, and writing are well suited to this approach.

There is strong evidence supporting the success of Complex Instruction strategies in promoting student academic achievement (Abram et al., 2001; Cohen, 1993, 1994a, 1994b; Cohen & Lotan, 1995; Cohen et al., 1999, 2002). In recent studies, evidence of this success has been extended to the learning gains of new English language learners.

Keys to Group Work

Recent research has gone beyond summative assessments of the benefits of group work to try to understand why collaboration benefits learning and to unpack the differences between more and less successful approaches to collaboration. A number of social processes have been identified that help explain why group work supports individual learning. They include opportunities to do the following: share original insights (Bos, 1937), resolve differing perspectives through argument (Amigues, 1988; Phelps & Damon, 1989), explain one's thinking about a phenomenon (King, 1990; Webb, Troper, & Fall, 1995), provide critique (Bos, 1937), observe the strategies of others (Azmitia, 1988), and listen to explanations (Coleman, 1998; Hatano & Iganaki, 1991; Webb, 1985; Schwartz, 1995; Shirouzu, Miyake, & Masukawa, 2002).

Definitions

Cooperative Learning
Small teams use a variety of learning activities to improve their understanding of a subject.

Design-Based Instruction
Students create, assess, and redesign products through stages of revisions. The work often requires collaboration and specific roles for individual students, enabling them to become experts in a particular area.

Inquiry-Based Teaching
A student-centered, active learning approach focusing on questioning, critical thinking, and problem solving.

Project-Based Learning
Students explore real-world problems and challenges, developing cross-curriculum skills while working in small collaborative groups. Also known as project learning.

Problem-Based Learning
Students learn through the process of solving a problem. The approach is also inquiry-based when students are active in creating the problem.

Researchers of collaborative learning situations note that it is not simply the act of asking children to work in groups that is essential, but rather the possibility that certain kinds of learning processes can be activated (Cohen, 1994b). Group members need to find ways to coordinate their attention and goals to work together productively (Barron, 2003). Research that attends explicitly to variability in group interaction has yielded information about factors affecting productive and less productive collaboration.

In an experimental study comparing the problem-solving of groups and individuals at the sixth-grade level, Barron (2000a, b; Barron 2003) found that groups outperformed individuals and that when students were given a new analogous problem to solve, those who had first solved the problems in groups performed at a significantly higher level. However, more detailed analysis revealed a great deal of variability in how well the students collaborated. Further analysis also showed that the quality of the collaboration—how they talked and interacted with one another—was related to their group score and later individual scores.

Given these and other findings, it's clear that the classroom teacher plays a critical role in establishing and modeling practices of productive group learning processes and conversations. Observing a group's interactions can provide teachers with valuable insight into whether the students are engaged in productive work and can provide the opportunity to offer formative feedback and to support the development of group understandings and goals. Computer-based tools can also be useful in establishing ways of working and supporting productive collaborative exchanges. One of the best and most documented examples is the Computer-Supported Intentional Learning (CSILE) project (Scardamalia, Bereiter, & Lamon, 1994), which includes a knowledge gathering and improvement tool to support inquiry and norms for knowledge building discourse. In their contemporary work, Scardamalia and Bereiter have expanded this pedegogical approach to "knowledge building communities" from K–12 to college level and workplace communities using the Knowledge Forum software environment. Beyond any specific tool or technique, however, it's important that the teacher establish, model, and encourage norms of interaction that reflect good inquiry practices.

Summary

There is strong evidence to show that inquiry-based, collaborative approaches to learning benefit both individual and collective knowledge growth. Students engaged in inquiry-based learning develop content knowledge and learn increasingly important twenty-first century skills, such as the ability to work in teams, solve complex problems, and to apply knowledge gained through one lesson or task to other circumstances.

The research also suggests that inquiry-based lessons and meaningful group work can be challenging to implement. They require simultaneous changes in curriculum, instruction, and assessment practices—changes that are often new to teachers, as well as students (Barron et al., 1998; Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991).

Teachers need time—and a community—to support their capacity to organize sustained project work. Without this additional time and support, extended projects can easily become more about "doing for the sake of doing" than "doing with understanding" (Barron et al., 1998), the true goal of inquiry-based group work.

As schools explore and implement strategies to engage and prepare students for the complex and ever-changing world, inquiry-based learning provides a research-proven approach withthat has the potential to transform teaching and learning. Students develop critical academic, interpersonal, and life skills and teachers, for their part, expand and deepen their repertoire, connecting with their peers and their students in new and powerful ways.

That's a powerful combination for students and teachers alike. ■

Inquiry-Based and Cooperative Learning in Action

Here is a list of short films and articles from the Edutopia website highlighting these practices in schools around the country:

- **FIRST** (For Inspiration and Recognition of Science and Technology) Robotics competition for high schools, founded by inventor and engineer Dean Kamen
edutopia.org/poudre-high-school-robotics

- **Build San Francisco**, a yearlong design program for high school students working with architects, organized by the Architectural Foundation of San Francisco
edutopia.org/learning-design

- **Expeditionary Learning**
Interdisciplinary projects by Maine middle school students, equipped with laptop computers
edutopia.org/king-middle-school-expeditionary-learning

- **Anchorage Alaska's** districtwide commitment to cooperative learning and the development of social and emotional skills
edutopia.org/anchorage-social-emotional-learning-video

REFERENCES

Abram, P., Scarloss, B., Holthuis N., Cohen, E., Lotan R., & Schultz, S. E. (2001). The use of evaluation criteria to improve academic discussion in cooperative groups. Asia Journal of Education, 22, 16–27.

American Association for the Advancement of Science. (1989). Science for All Americans: Project 2061. New York: Oxford University Press, 1989.

Achilles, C. M., & Hoover , S. P. (1996). Transforming administrative praxis: The potential of problem-based learning (PBL) as a school-improvement vehicle for middle & high schools. Annual Meeting of the American Educational Research Association, New York.

Albanese, M. A., & Mitchell, S. A. (1993). "Problem-based learning: A review of literature on its outcomes and implementation issues." Academic Medicine, 68(1), 52–81.

Amigues, R. (1988). Peer interaction in solving physics problems: Sociocognitive confrontation and metacognitive aspects. Journal of Experimental Child Psychology, 45(1), 141–158.

Barron, B. (2000a). Achieving coordination in collaborative problem-solving groups. Journal of the Learning Sciences, 9(4), 403–436.

Barron, B. (2000b). Problem solving in video-based microworlds: Collaborative and individual outcomes of high-achieving sixth-grade students. Journal of Educational Psychology, 92(2), 391–398.

Barron, B. (2003). When smart groups fail. Journal of the Learning Sciences, 12(3), 307–359.

Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., et al. (1998). Doing with understanding: Lessons from research on problem- and project-based learning. Journal of the Learning Sciences, 7(3–4), 271–311.

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. In New Directions for Teaching and Learning, no. 68 (pp. 3–11). San Francisco: Jossey-Bass.

Bartscher, Gould, & Nutter, 1995. Increasing student motivation through project-based learning. Master's research project, Saint Xavier and IRI Skylight. (ED 392549).

Blumenfeld, P., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. Educational Psychologist, 26(3 & 4), 369–398.

Boaler, J. (1997). Experiencing school mathematics: Teaching styles, sex, and settings. Buckingham, UK: Open University Press.

Boaler, J. (1998). Open and closed mathematics: Student experiences and understandings. Journal for Research in Mathematics Education, 29, 41–62.

Bos, M. C. (1937). Experimental study of productive collaboration. Acta Psychologica, 3, 315–426.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (1999). How people learn: Brain, mind, experience, and school. Washington, DC: National Research Council.

Cohen, E. G. (1994a). Designing groupwork: Strategies for heterogeneous classrooms, Revised edition. New York: Teachers College Press.

Cohen, E. G. (1994b). Restructuring the classroom: Conditions for productive small groups. Review of Educational Research, 64(1), 1–35.

Cohen, E. G., & Lotan, R. A. (1995). Producing equal-status interaction in the heterogeneous classroom. American Educational Research Journal, 32(1), 99–120.

Cohen, E. G., & Lotan, R. A. (Eds.). (1997). Working for equity in heterogeneous classrooms: Sociological theory in practice. New York: Teachers College Press.

Cohen, E. G., Lotan, R. A., Abram, P. L., Scarloss, B. A., & Schultz, S. E. (2002). Can groups learn? Teachers College Record, 104(6), 1045–1068.

Cohen, E. G., Lotan, R. A., Scarloss, B. A., & Arellano, A. R. (1999). Complex instruction: Equity in cooperative learning classrooms. Theory into Practice, 38(2), 80–86.

Cohen, P. A., Kulik, J. A., & Kulik, C. C. (1982). Education outcomes of tutoring: A meta-analysis of findings. American Educational Research Journal, 19, 237–248.

Coleman, E. B. (1998). Using explanatory knowledge during collaborative problem solving in science. Journal of the Learning Sciences, 7(3–4), 387–427.

Cook, S. B., Scruggs, T. E., Mastropieri, M. A., & Castro, G. C. (1985). Handicapped students as tutors. Journal of Special Education, 19, 483–492.

Cornelius, L. L., & Herrenkohl, L. R. (2004). Power in the classroom: How the classroom environment shapes students' relationships with each other and with concepts. Cognition and Instruction, 22(4), 467–498.

Darling-Hammond, L. & Hammerness, K. (2002). Toward a pedagogy of cases in teacher education. Teaching Education, 13(2), 125-135.

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. Learning and Instruction, 13, 533–568.

Edelson, D., Gordon, D., & Pea, R. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. Journal of the Learning Sciences, 8(3&4), 391–450.

Fortus, D., Dershimer, R. C., Marx, R. W., Krajcik, J., & Mamlok-Naaman, R. (2004). Design-based science (DBS) and student learning. Journal of Research in Science Teaching, 41(10), 1081–1110.

Gallagher, S. A., Stepien, W. J., & Rosenthal, H. (1992). The effects of problem-based learning on problem solving. Gifted Child Quarterly, 36, 195–200.

Gertzman, A., & Kolodner, J. L. (1996, July). A case study of problem-based learning in middle-school science class: Lessons learned. In Proceedings of the Second Annual Conference on the Learning Sciences (pp. 91–98), Evanston/Chicago.

Ginsburg-Block, M. D., Rohrbeck, C. A., & Fantuzzo, J. W. (2006). A meta-analytic review of social, self-concept, and behavioral outcomes of peer-assisted learning. Journal of Educational Psychology, 98, 732–749.

Good, T. L., & Brophy, J. E. (1986). Educational Psychology (3rd ed.). New York: Longman.

Hartley, S. S. (1977). A meta-analysis of effects of individually paced instruction in mathematics. Unpublished doctoral dissertation, University of Colorado at Boulder.

Hatano & Ignaki. (1991). Sharing cognition through collective comprehension activity. In L. B. Resnick, J. Levine, & S. Teasley (Eds.), Perspectives on socially shared cognition (pp. 331–348). Washington, DC: American Psychological Association.

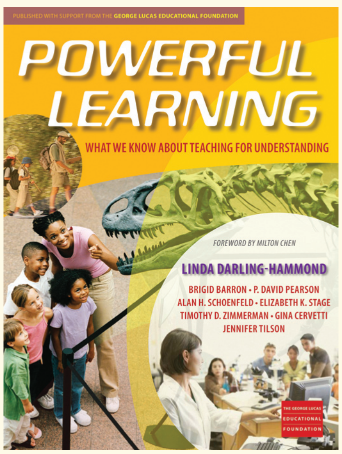
Hmelo, C. E. (1998b). Problem-based learning: Effects on the early acquisition of cognitive skill in medicine. Journal of the Learning Sciences, 7(2), 173–208.

Hmelo, C. E., Holton, D. L., & Kolodner, J. L. (2000). Designing to learn about complex systems. Journal of the Learning Sciences, 9(3), 247–298.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? Educational Psychology Review, 16(3), 235–266.

Johnson, D. W., & Johnson, R. T. (1981). Effects of cooperative and individualistic learning experiences on interethnic interaction. Journal of Educational Psychology, 73, 444–449.

Johnson & Johnson 1989). Cooperation and competition: Theory and research. Edina, MN: Interaction Book Company.
Johnson, D. W. Johnson, R. T. (1999). Making cooperative learning work. Theory into practice, 38(2), 67-73.
Johnson, D. W., Maruyama, G., Johnson, R., Nelson, D., & Skon, L. (1981). Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. Psychological Bulletin, 89, 47–62 (http://dx.doi.org/10.1037/0033-2909.89.1.47).
King, A. (1990). Enhancing Peer Interaction and Learning in the Classroom Through Reciprocal Peer Questioning. American Educational Research Journal, 27(4), 664–687.
Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., Bass, K. M., Fredericks, J., & Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. Journal of the Learning Sciences, 7, 313–350.
Marx, R. W., Blumenfeld, P. C., Krajcik, J, Blunk, M., Crawford, B., Kelly B., and Meyer, K. (1994). Enacting project-based science: Experiences of four middle grade teachers. Elementary School Journal, 94(5), 499–516.
Moore, A., Sherwood, R., Bateman, H., Bransford, J., & Goldman, S. (1996, April). Using problem-based learning to prepare for project-based learning. Paper presented at the annual meeting of the American Educational Research Association, New York.
Newmann, F. M. (1996). Authentic achievement: Restructuring schools for intellectual quality. San Francisco: Jossey-Bass.
Newmann, F. M., Marks, H. M., & Gamoran, A. (1995). Authentic pedagogy: Standards that boost student performance. Issues in Restructuring Schools, 8, 1–4.
Newstetter, W. (2000). Bringing design knowledge and learning together. In C. Eastman, W. Newstetter, & M. McCracken (Eds.), Design Knowing and Learning: Cognition in Design Education. New York: Elsevier Science Press.
O'Donnell, A. M. (2006). The role of peers and group learning. In P. Alexander & P. Winne (Eds.), Handbook of Educational Psychology (2nd ed.). Mahwah, NJ: Erlbaum.
O'Donnell, A. M., & Dansereau, D. F. (1992). Scripted cooperation in student dyads: A method for analyzing and enhancing academic learning and performance. In R. Hertz-Lazarowitz & N. Miller (Eds.), Interaction in cooperative groups: The theoretical anatomy of group learning. Cambridge, MA: Cambridge University Press.
Palincsar, A. S., & Herrenkohl, L. (1999). Designing collaborative contexts: Lessons from three research programs. In A. M. O'Donnell & A. King (Eds.), Cognitive perspectives on peer learning (pp. 151–177). Mahwah, NJ: Erlbaum.
Palincsar, A. S., & Herrenkohl, L. (2002). Designing collaborative learning contexts. Reading Teacher, 41(1), 26–32.
Peck, J. K, Peck W., Sentz, J., & Zasa, R. (1998). Students' perceptions of literacy learning in a project-based curriculum. In E. G. Sturtevant, J. A. Dugan, P. Linder, & W. M. Linek (Eds.), Literacy and Community (pp. 94–100). Texas A&M University: College Reading Association.
Penuel, W. R., Means, B., & Simkins, M. B. (2000). The multimedia challenge. Educational Leadership, 58, 34–38.
Perkins, D. N. (1986). Knowledge as design. Hillsdale, NJ: Erlbaum.
Phelps, E., & Damon, W. (1989). Problem solving with equals: Peer collaboration as a context for learning mathematics and spatial concepts. Journal of Educational Psychology, 81(4), 639–646.
Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. Journal of Research in Science Teaching, 42(2), 185–217.
Quin, Z., Johnson, D., & Johnson, R. (1995). Cooperative versus competitive efforts and problem solving. Review of Educational Research, 65(2), 129–143.
Rohrbeck, C. A., Ginsburg-Block, M. D., Fantuzzo, J. W., & Miller, T. R. (2003). Peer-assisted learning interventions with elementary school students: A meta-analytic review. Journal of Educational Psychology, 95, 240-257 (http://dx.doi.org/10.1037/0022-0663.95.2.240)
Rosenfeld, M., & Rosenfeld, S. (1998). Understanding the "surprises" in PBL: An exploration into the learning styles of teachers and their students. Paper presented at the European Association for Research in Learning and Instruction (EARLI), Sweden.
Savery, J. R., & Duffy, T. M. (1996). Problem based learning: An instructional model and its constructivist framework. In B. G. Wilson (Ed.), Constructivist learning environments. Englewood, NJ: Educational Technology Publications, pp. 135–148.
Scardamalia, M., Bereiter, C., & Lamon, M. (1994). The CSILE project: Trying to bring the classroom into world 3. In K. McGilly (Ed.), Classroom lessons: Integrating cognitive theory & classroom practice (pp.201–228). Cambridge, MA: MIT Press.
Schmidt, H. G., et al. (1996). The development of diagnostic competence: A comparison between a problem-based, an integrated, and a conventional medical curriculum. Academic Medicine, 71, 658–664.
Schwartz, D. L. (1995). The emergence of abstract representations in dyad problem solving. Journal of the Learning Sciences, 4(3), 321–354.
Shirouzu, H., Miyake, N., & Masukawa, H. (2002). Cognitively active externalization for situated reflection. Cognitive Science, 26(4), 469–501.
Slavin, R. (1991, February). Synthesis of research on cooperative learning. Educational Leadership, 71–82.
Slavin, R. E. (1996). Research on cooperative learning and achievement: What we know, what we need to know. Contemporary educational psychology, 21(1), 43–69.
Slavin, R., & Oickle, E. (1981). Effects of cooperative learning teams on student achievement and race relations: Treatment by race interactions. Sociology of education, 54(3), 174–180.
Stepien, W. J., Gallagher, S. A., & Workman, D. (1993). Problem-based learning for traditional and interdisciplinary classrooms. Journal for the Education of the Gifted Child, 16, 338–357.
Thomas, J. W. (2000). A review of project based learning. (Prepared for Autodesk Foundation).
Vernon, D. T., & Blake, R. L. (1993). Does problem-based learning work? A meta-analysis of evaluative research. Academic Medicine, 68(7) 550–563.
Webb, N. M. (1985). Verbal interaction and learning in peer-directed groups. Theory into Practice, 24(1), 32–39.
Webb, N. M., Troper, J. D., & Fall, R. (1995). Constructive activity and learning in collaborative small groups. Journal of educational psychology, 87(3), 406–423.
White, B., & Frederiksen, J. (2005). A theoretical framework and approach for fostering metacognitive development. Educational Psychologist, 40(4), 211–223.
Williams, S. M. (1992). Putting case-based instruction into context: Examples from legal and medical education. Journal of the Learning Sciences, 2(4), 367–427.
Williams, D. C., Hemstreet, S., Liu, M., & Smith, V. D. (1998). Examining how middle schools students use problem-based learning software. Proceedings of ED-MEDIA/ED-Telecom 98 World Conference on Educational Multimedia and Hypermedia, Freiburg, Germany.



Editor's Note: This article, edited by Roberta Furger, is excerpted from a chapter of a new book, *Powerful Learning: What We Know About Teaching for Understanding.*

By Linda Darling-Hammond, Brigid Barron, P. David Pearson, Alan H. Schoenfeld, Elizabeth K. Stage, Timothy D. Zimmerman, Gina N. Cervetti, and Jennifer Tilson

Published by Jossey-Bass, a Wiley imprint.
989 Market Street
San Francisco, CA 94103-1741
josseybass.com

Published with support from
The George Lucas Educational Foundation

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