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ABSTRACT

Cognitive science research indicates that learning through apprenticeship may be more effective than traditional schooling. The following critical mistakes in traditional schooling are outlined: (1) skills are taught in progressively more difficult steps, neglecting to engage higher-order thinking abilities; (2) a skill is broken down into separately practiced subskills, which seldom produces competence in the skill itself; (3) skills are taught in isolation, providing little experience in how they are used in combination; (4) knowledge, skills, and their application are separated, preventing true understanding; and (5) knowledge and skills are taught in a classroom setting unlike settings at work or in real life, impeding the transfer of learning. The following contrasts between in-school and out-of-school mental activity are outlined: (1) school emphasizes individual work while out-of-school situations require group problem-solving; (2) school emphasizes pure mentation while out-of-school situations emphasize the use of tools; (3) school emphasizes symbol manipulation while out-of-school situations emphasize things and events; and (4) school emphasizes generalized learning while out-of-school situations emphasize situation-specific competencies. Successful apprenticeship programs share the following characteristics: (1) focus on the conditions of application of the knowledge and skills being learned; (2) weave together specific declarative and procedural knowledge with the development of general basic skills and problem-solving strategies; (3) take into account the learner's original ideas, stage discrepant or confirming experiences to stimulate questions, and encourage the generation of a range of responses with the opportunity to apply these in various situations; and (4) emphasize learning in context. (FMW)

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PREFACE

The National Center on Education and Employment is funded by the Office of Educational Research and Improvement (OERI) of the U.S. Department of Education. The Center is based at Teachers College, Columbia University, in New York City. The RAND Corporation of Santa Monica, California, and Washington, D.C., is a partner with Teachers College in this enterprise.

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INTRODUCTION

The challenge facing efforts to improve American schooling is so great that it requires nothing less than a complete reframing of our education and training systems and workplaces as learning environments. In other words, we are talking about a revolution in our economic and educational institutions.

"Workplace literacy" is a big playing field, and could be attacked from any one of several angles. One of the most promising approaches is a powerful and pioneering research base—the cognitive sciences. This research is a slash across the canvas for schooling and training of all kinds—whether elementary and secondary education, college, professional schools, adult literacy programs, military training, or corporate training. It challenges what we teach, when we teach it, and how we teach it.

At the heart of this research is the presumption that intelligence and expertise are built out of interaction with the environment, not in isolation from it. It thus challenges our traditional and treasured distinctions between:

- head and hand
- academic and vocational education
- knowing and doing
- abstract and applied
- education and training, and
- school-based and work-based learning.[1]

Questions that this research answers or for which it has relevance include the following. What is known about the differences between effective performance and less skilled performance, and how do individuals acquire expertise in a job? What are the relationships between what are usually considered basic or general skills (literacy, numeracy, reasoning skills, ability to solve problems), knowledge in a specific domain, and competency in a related job or profession? How

[1] These remarks rely heavily on three documents, all of them syntheses of the educational implications of the cognitive sciences: Lauren B. Resnick, "Learning In School and Out," *Educational Researcher*, 16 (9):13-20; Senta A. Raizen, *Reforming Education for Work: A Cognitive Science Perspective*, in press, the Institute on Education and the Economy, Teachers College, Columbia University, and the National Center for Research on Vocational Education, University of California at Berkeley; and Senta A. Raizen's briefing at the conference, "Edcuation and the Economy: Hard Questions, Hard Answers," sponsored by the Institute on Education and the Economy, September 5-7, Brewster, Massachusetts.

do people actually solve problems on the job, and what are the skills and competencies that characterize good work performance? How effectively do people transfer their formal school-based instruction to situations outside school and apply it on the job? What is the role of apprenticeship, and what are its modern equivalents?

Given the evidence about the acquisition and effective use of job knowledge to produce competent performance, how should workplace literacy programs be formulated? Should they be offered in formal school-like settings and be integrated with traditional school subjects? Or should they be offered in work settings and integrated with on-the-job education? How would work arrangements have to change to facilitate an effective equivalent of apprenticeship training?

Although the implications of this work have been used primarily to critique elementary and secondary education, the nation's educational and training systems do not differ particularly in their pedagogic strategies, whatever the rhetoric about their differences. Indeed, all of these systems have very limited success because they have similar pedagogic problems. Americans share the common experience of elementary and secondary schooling. This shared experience pervasively, implicitly, and powerfully frames our ideas and models of what learning environments should look like, whether called a college classroom, an adult literacy class, or a corporate training classroom. Thus, the pedagogic problems of our elementary and secondary schools get reproduced even in training systems that we like to think of as non-traditional, such as workplace literacy programs.

I want to accomplish three things in this paper: (1) describe five critical pedagogical mistakes identified by this research; (2) contrast in-school and out-of-school mental activity to illustrate the mismatch between the two settings in the nature and structure of knowledge used and the social and technological contexts of its use; and (3) begin to sketch what more effective learning environments might look like.

FIVE MISTAKES IN EDUCATION AND TRAINING

Let's start with the five critical mistakes that we persistently make in education and training.

First: Most school- and work-based training operates on the assumption that skills are like building blocks, that people must learn "the basics" or "first things first" before they can learn specific technical or problem-solving skills. For example, if we teach higher-order cognitive thinking skills at all, we usually assume that these skills can be developed only in the later years of school. Research has demonstrated that these assumptions are simply not valid. Human beings—even small children—are quintessentially sense-making, problem-solving animals. By not involving the child's sense-making inclinations in early learning, we miss opportunities to begin honing higher-order cognitive thinking abilities, and we create barriers to learning the material that we are trying to teach. All too often, we repeat these errors in adult and workplace literacy programs.

Second: Often a skill is decomposed into subskills, and each subskill is practiced separately. But it is seldom true that learning each of the subskills separately produces competence in the skill itself.

Third: Skills are taught in isolation, with too little experience with their application or of how they are used in combination. Appropriate application of knowledge and skills is not automatic.

Fourth: Separating "learning to know" and "learning to do" is dysfunctional. The sharp boundary between academic learning and education for work is an artifact of the industrial age. The assumption that they need to be separated for effective learning does not hold. Knowledge, skills, and their application are inseparable; there is no effective understanding of one without the other two.

Fifth: At present, knowledge and skills are taught in a setting—the formal classroom—very unlike settings at work or in real life. This teaching out of context impedes the transfer of school learning to settings outside the classroom.

CONTRASTS BETWEEN IN-SCHOOL AND OUT-OF-SCHOOL MENTAL ACTIVITY

Let's look at the differences between in-school and out-of-school mental activity and the social and technological contexts for this activity.

The first contrast is between individual cognition in school and school-like training programs versus shared cognition outside. Although group activities occur in school, students are ultimately judged on what they can do by themselves. Much of the core activity of the school—homework or in-class exercises—is designed as individual work. For the most part, students fail or succeed at a task independently of what other students do. By contrast, a great deal of activity outside of school is socially shared: work, personal life, and recreation take place in social systems in which what one person is able to do depends fundamentally on what others do and in which "successful" functioning depends upon the mesh of several individuals' mental and physical performances. This contrast argues for much more team and cooperative learning in workplace literacy programs, with the student being held accountable for both individual and team performance.

The second contrast is between pure mentation in school versus tool manipulation. In school, the greatest premium is placed on "pure thought" activities—what individuals can do without dependence on "external crutches"—whether books and notes, calculators, or other complex instruments. While some of these tools may be used, even encouraged, during "learning," they are almost always absent during tests of performance. Thus, school becomes an institution that values thought that is independent of the physical and cognitive tools that are a vital and defining part of virtually all practical activity. Out of school, by contrast, most mental activities are intimately involved with and shaped by the physical and intellectual tools available, and the criteria for competence include the expert use of tools. This contrast suggests that student performance should be both developed and assessed relative to the student's abilities to make effective use of tools, not independent of them.

The third contrast is between symbol manipulation in school versus reasoning about things and situations that make sense to people outside of school. Outside of school, actions are intimately connected with things and events, and because people are engaged with things and situations that make sense to them, they do not fall into the trap of forgetting what their calculations or their reasoning is about. Their mental activities make sense in terms of their immediate effects, and their actions are grounded in the logic of immediate situations. In school, however, learning is symbol-based to such an extent that connections to the things being symbolized are often lost. School and school-like learning then become a matter of learning rules and saying or writing things according to the rules, whether or not they make sense to the student.

This focus on symbols detached from their referents creates difficulties even for school learning itself. For example, Sticht found that marginally literate adults in a job-related reading program made twice the gain in job-related reading than they made in general reading—that is, they did better when a meaningful context was provided for the text.

We see the same thing in science learning. Both younger and older students bring to science learning their own conceptions of natural phenomena, such as light, heat and temperature, electricity, or physical and chemical transformations. These ideas are personal, that is, constructed out of their interpretations of naive experience, coherent in their own terms, and very resistant to change through traditional school instruction.

The time devoted to a lesson or even a series of lessons on a particular topic hardly suffices to change individuals' strongly held ideas that they bring with them to school. Yet, traditional curriculum design usually is based on a conceptual analysis of the subject matter that ignores what is already in the learner's head, with the result that students can play back memorized canonical knowledge and conceptions but return to their own ideas when confronted with unfamiliar questions or non-routine problems. For example, even students in college physics courses designed for physics majors can solve "book" problems in Newtonian mechanics by rote application of formulae, but—even after instruction—revert to naive pre-Newtonian explanations of common physical situations.

The argument is not that abstractions should not be taught; it is that they will be better understood when instruction uses the knowledge that students bring with them to the task and when their meaning is explored in detail within specific situations to which they apply and which are meaningful contexts to the student. Specifically, instruction must be designed to bring about conceptual change. How can this be accomplished?

- Provide opportunities for pupils to make their own ideas explicit.
- Introduce discrepant events to stimulate questions and examination of assumptions.
- Use Socratic questioning.
- Encourage the generation of a range of conceptual schemes.
- Give students practice in using ideas in a variety of situations.[2]

[2] Driver, Rosalind. Guesne, Edith, and Tiberghien, Andree, eds. *Children's Ideas in Science.* Philadelphia: Open University Press, 1985.

The fourth contrast is between generalized learning in the classroom versus situation-specific competencies outside. In school we aim for general, widely usable skills and theoretical principles. Indeed, the major claim for school-type instruction is, usually, its generality and power of transfer. Yet outside, to be truly skillful, people must develop situation-specific forms of competence. We find that the "packages" of knowledge and skill that schools provide do not map directly onto the clusters of knowledge that students will actually use in their work. This seems true even for highly technical knowledge, where schooling is intended to provide direct professional training. Studies of expert radiologists, electronic trouble-shooters, and lawyers all reveal a surprising lack of transfer of theoretical principles, processes, or skills learned in school to professional practice. For example, Morris and Rouse found that extensive training in electronics and troubleshooting theories provided very little knowledge and even fewer skills directly applicable to performing electronic troubleshooting.[3] All of this points toward the possibility that very little can be transported directly from school—as it is now constituted—to out-of-school use. The structure of the knowledge used and the social structure of its use may be more fundamentally mismatched than we had previously thought.

This does *not* mean that individuals would be better off if not taught formal algorithms. No one would argue that the power conferred by formal algorithms is irrelevant. Rather, the issue is how to help people recognize and use that power.

MODERN APPRENTICESHIP

Finally, if traditional schooling and school-like training programs are not particularly effective, what is? The streams of cognitive research come together in a renewed interest in learning through apprenticeship—not, however, in traditional craft apprenticeships. Traditional apprenticeships, since they involve little explicit teaching and depend primarily on learning by observation, will not work for most modern job situations. In many jobs today, it would not be possible for a novice, merely through observation, to learn what the expert does or why. Individual and group tasks have become opaque; the technology has become complex, hidden, or automated. Thus, little is to be seen, understood, or mastered by simply being on the scene, especially in the absence of explicit explanations for why various operations are being engaged in.

[3] Morris, Nancy and Rouse, William, "Review and Evaluation of Empirical Research in Troubleshooting." *Human Factors*. 27:503-530.

Thus, little is to be seen, understood, or mastered by simply being on the scene, especially in the absence of explicit explanations for why various operations are being engaged in.

Cognitive science analyses of competence, including the identification of differences between novices and experts, have made possible the formal modeling and simulation of complex cognitive performance, leading to a number of successful education and training programs that constitute modern apprenticeships under the tutelage and mentorship of experts. These programs have several characteristics in common.

- They do not just teach knowledge and procedures; they also focus on the conditions of application of the knowledge and skills being learned.

- They weave together specific declarative—"know what"—and procedural—"know how"—knowledge with the development of general basic skills and problem-solving strategies.

- Instead of constructing curriculum top-down by encoding the knowledge of experts in suitably simplified materials, instruction takes into account the learner's original ideas, stages discrepant or confirming experiences to stimulate questions, and encourages the generation of a range of responses with the opportunity to apply these in various situations.

- Finally, effective programs acknowledge the importance of learning in context. They use the physical environment and the tools it provides to represent problems and develop solutions. They foster the cooperative construction of knowledge among groups of workers doing a common task or exchanging information about related tasks. And they help the learner become part of the community that shares a particular domain of knowledge, set of skills, and ways of representing and resolving problems.

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