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ABSTRACT

Using cognitive science as a lens, this report identifies serious problems with most learning situations, maps the design principles for more effective learning, and shows how these principles relate to four policies and programs: integrating academic and vocational education, work-based apprenticeship, tech prep and 2+2, and cooperative education. Following an executive summary, Chapter 1 notes problems in existing education and training systems. Chapter 2 discusses the following assumptions about learning that are believed to be incorrect: (1) people predictably transfer learning; (2) learners are best seen as passive vessels into which knowledge is poured; (3) learning is the strengthening of bonds between stimuli and correct responses; (4) learners are blank slates on which knowledge is inscribed; and (5) to be transferable to new situations, skills and knowledge should be acquired independent of their contexts of use. Chapter 3 addresses 19th-century educational ideas, the child as spectacular learner, and traditional apprenticeship learning. Chapter 4 looks at cognitive apprenticeship models, defining characteristics of cognitive apprenticeship, examples of cognitive apprenticeship, and learning environments. Chapter 5 discusses integration of academic and vocational education, work-based learning, tech prep, cooperative education, and the effectiveness of cognitive apprenticeship. A calendar of National Council on Vocational Education meetings and activities, a list of council members, and 46 references conclude the document. (CML)

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1990-91

Contents

Foreword

The major focus of the National Council on Vocational Education has been to provide answers and possible solutions to improving the results of education. With this focus in mind, the following initiatives were implemented by the Council during 1990-91:

- Business, Industry and Education Forum—Time for Action
- Summary of the Cognitive Science Research and Its Implication for Education
- Occupational Competency Working Committee Reports for:
  - *Work Ethic/Self-Esteem*
  - *Manufacturing*
  - *Aviation Maintenance*
  - *Printing Industry*
- National Awards Recognizing Outstanding Achievements
- Regional Seminars for Large School Districts on the Carl D. Perkins Vocational and Applied Technology Education Act

This report, as well as other National Council reports, should be used to provide "Solutions" to increasing students' options for a sound and productive education. "Solutions", the Council's annual report, describes what a quality vocational-technical education program should include and summarizes cognitive science research and its implication on education.

There are answers for education reform with proven success. It is time to make changes not just wish for changes.

"Quality" Vocational-Technical Education

What Is It?

"Quality" vocational-technical education is essential to provide the workforce the United States must have to be internationally competitive. The best vocational-technical education may be identified by different titles (occupational education, education for employment, technical education) but will include the following elements:

1. **Establishes a close working relationship with business/industry.**
   A mutually beneficial partnership is established. Business/industry help identify the competencies to be taught, offer cooperative education programs and internships, and readily hire the graduates. When available, the program utilizes standards developed by business/industry and education to improve the program and insure its relevance.

2. **Hires instructors who have had experience in the business and industry that they are teaching.**
   Teachers understand the needs of employers and continually update their knowledge and skills. Opportunities for teachers to work in business/industry and for employees in business/industry to work in education should be provided (cross employment).

3. **Integrates vocational student organizations into the classroom.**
   They reinforce concepts taught in the classroom through student-directed activities with opportunities to serve the community and develop leadership skills.

4. **Integrates academic and vocational-technical education concepts.**
   This allows both academic (science, math, communications, etc.) and vocational-technical education teachers to meet together to change and coordinate their curriculums to provide students with knowledge and skills that they can use in the "real world".

   It is essential that students are provided with access to *higher level academic courses that seek to teach vocational-technical students through cooperative and applied learning strategies. The workplace requires a higher level of academic skills and the knowledge to apply these skills. Three years of lower level "general" math, science and English will not* provide the competencies needed.

5. **Coordinates secondary and postsecondary vocational-technical education programs.**
   Through coordinating or articulating programs at the high school level with two years of postsecondary education and then with the completion of a bachelor's degree (tech prep or 2 + 2 + 2), students are able to move to a higher level of technical skills and knowledge. Many students can set goals which will provide them with a better job and a career ladder to success.

6. **Makes a commitment to career awareness and planning for students.**
   Students understand the career options available, are taught to set goals, and have the self-esteem and belief in themselves to pursue those goals.

   A quality program provides students with an understanding of the entire scope of the industry (cluster approach). A broader range of knowledge and skills will help students to be more employable, have more options and be able to change as the industry requires.

7. **Has access to and coordinates with a modern technology education component.**
   Technology education provides students with knowledge about how technology impacts them as future employees, consumers and voters. It also gives them an awareness of career possibilities.

8. **Gives students opportunities to develop critical thinking, problem solving, team work skills and a commitment to life-long learning, especially self-teaching.**
   These are the skills that are required by business/industry and will help the students be employable and productive.

   Set high expectations for students in class and outside of class. Students usually reach the level of expectations set for them. Even high school students agree that the level of expectations is too low.

9. **Uses an on-going evaluation procedure to constantly improve the program and insure that it is teaching the skills and competencies that employers need.**
   The evaluation would include feedback from former students, from current employers and assess the job market needs.

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Who Is It For?

"Quality" vocational-technical education will benefit all students:

- **Students seeking employment** will need a higher level of academic skills, knowledge and skills of the industry in which they will be working (terminology, safety, use of basic equipment), and a strong work ethic. Vocational-technical education graduates must work with their "minds" and their hands. Would you want to fly on an airplane that was maintained and repaired by a technician who did not think about what he/she was doing?

- **College prep students** need knowledge of practical application of theories. For instance, many employers are complaining that recent engineer graduates from a university have no practical knowledge, only theory. These graduates lack information about how materials perform, computer aided design and actual construction of buildings.

- **Technical students** who are pursuing an associate degree will be better prepared to master the competencies required. Especially where Tech Prep (articulation of 2 years of high school and 2 years of a community college or technical institute) is available, students will be prepared to meet the demands of the modern workplace.

- **University dropouts** will need competencies which will help them get a productive job. Many students will attend only one semester or one year of a four-year university and will quit for various reasons. As a nation, we cannot afford for them to float in the economy taking odd jobs until they are 28 years old. It is a waste of a precious resource we need.

- **University graduates** will often return to community colleges or technical institutes to obtain employment skills when they cannot get a job or want to change their career direction.

When Should It Be Provided?

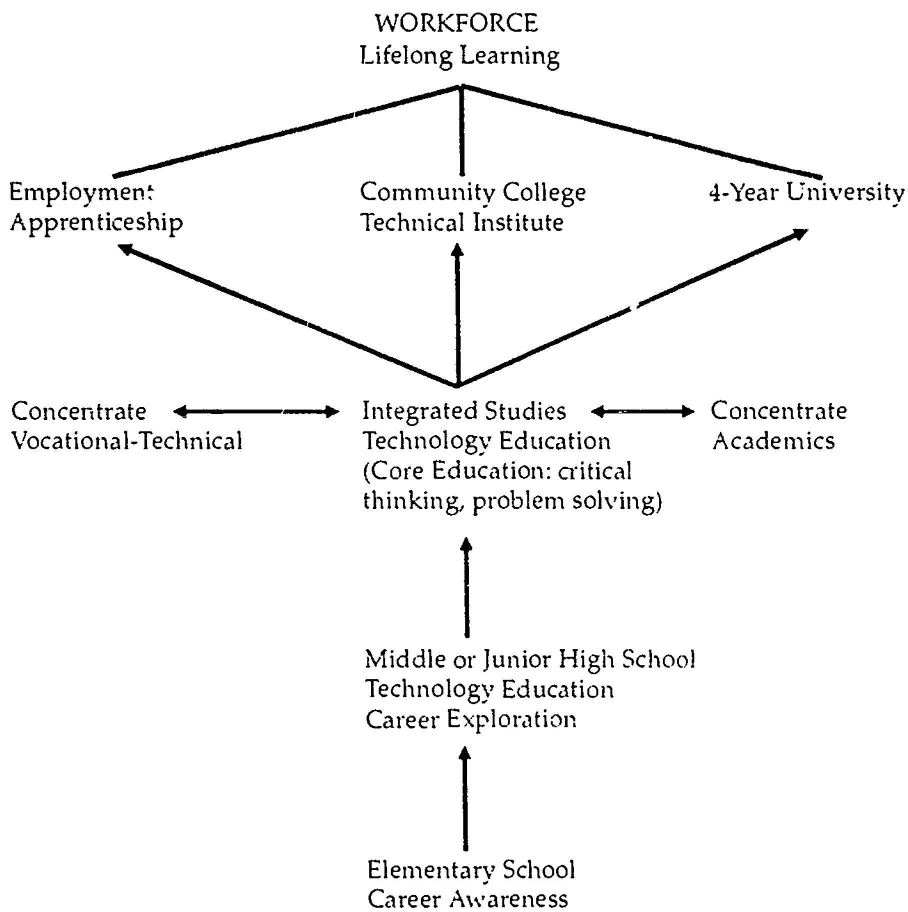
Various aspects of education (academics, fine arts, vocational-technical, life skills) should be provided to all individuals during their lifetime. It is *not* an either-or situation. We do need to help youth and adults decide when and how to incorporate them in their lifelong education plan. The same plan does not work for everyone.

How Will It Exist?

"Quality" vocational-technical education can only exist when it is made a priority by national, state and local leaders. School board members, superintendents, principals, teachers and employers must be committed to make it happen. The best programs will serve all range of students, parents will be anxious to have their children in them, and adults will enhance their career ladder options.

Quality education helps the individual to lead a more productive, satisfying and happier life. All of which makes for a better lifestyle and a stronger nation.

LIFELONG LEARNING



Summary of the Cognitive Science Research and Its Implications for Education

—Designing Effective Learning Environments—

Prepared for the

National Council on Vocational Education

by

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Executive Summary

Using the lens of a powerful knowledge base, known as "cognitive science," this paper identifies the serious problems with most K-12 learning situations, maps the design principles for more effective learning, and shows how these principles relate to four policies and programs: integrating academic and vocational education, work-based apprenticeship, technical preparation and 2+2, and cooperative education.

Schools routinely and profoundly violate what we now know about how people learn the most effectively and the conditions under which they apply their knowledge appropriately to new situations.

The knowledge base for this indictment, cognitive science, is an interdisciplinary field that includes psychologists, linguists, anthropologists, computer scientists, philosophers, and neuroscientists. The word "cognitive" refers to perceiving and knowing. Their research is very diverse, but includes observing children learning mathematics or experienced workers handling the cognitive demands of their jobs.

Five Assumptions About Learning—All Wrong

Most educators make five assumptions about learning—*all wrong*.

People predictably transfer learning

The first assumption is that *people predictably transfer learning*. We assume that the point of schooling is to prepare students for effective functioning in non-school settings, which include, but are not limited to, the workplace. Accepting this assumption means that we have to confront what is known as the "knowledge transfer problem." "Knowledge transfer" simply means the appropriate use in a new situation of concepts, skills, knowledge, and strategies acquired in another.

Research, extensive and spanning decades, shows that individuals do not predictably transfer knowledge in any of three situations where transfer should occur. They do not predictably transfer school knowledge to everyday practice. They do not predictably transfer sound everyday practice to school endeavors, even when the former seems clearly relevant to the latter. They do not predictably transfer their learning across school subjects.

Learners are best seen as passive vessels into which knowledge is poured

The second assumption is that *learners are best seen as passive vessels into which knowledge is poured*. In a typical schoolroom, a Congressional hearing, or a corporate training

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session, the teacher—or "expert"—faces the learners, in the role of knowledge source. The learner is the passive receiver of wisdom—a glass into which water is poured.

This instructional arrangement comes out of an implicit assumption about the basic purpose of education: the transmission of the society's culture from one generation to the next. The concept of transmission implies a one-way flow from the adult members of the society to the society's entering members (the young)—or from the expert to the novice. Education thus becomes the conveying of what experts know to be true, to the student as receiver of the Word, to a lecture mode of teaching, and to the teacher as the controller of the process.

Passive learning has destructive consequences that educators in fact do not want but that their ways of organizing learning produce.

- **Passive learning reduces or removes chances for exploration, discovery and invention.** Passive learning means that learners do not get the experiential feedback so key to learning. The student needs chances to engage in choice, judgment, control processes, problem formulation; he/she needs the chance to make mistakes. The adage, "Experience is the best teacher,"—you learn when you do—is borne out by the research.

- **Passive learning places control over learning in the teacher's, not the learner's, hands.** Passive learning creates learners dependent on teachers for guidance and feedback, thus undercutting the development of confidence in one's ability to learn and initiate cognitive executive skills. In one example from the research, students were asked to solve school math problems like ones that they had mastered outside of school. The problems were even presented in contexts the same as those outside of school which they had mastered. Their responses revealed that they had no sense of control over school problems. They guessed wildly, ran to their teacher for confirmation and help, and showed no confidence that their non-school experiences could help them.

The research shows what is happening here. Individuals experience themselves as both subjects and objects in the world. Outside of school, as in the supermarket, people experience themselves as in control of their activities. They can interact with the setting, generate problems and solutions in relation to the setting, and control of the problem solving processes. School, however, creates contexts in which children experience themselves as objects, with no control over problems or choice about problem solving processes. Control in the teachers' hands, not the students', undercuts students' trust in their own sense-making abilities. As important, it also undercuts the development of a particular set of higher-order cognitive skills, the "cognitive self-management" or "executive thinking" skills. These include goal setting, strategic planning, checking for accurate plan execution, goal-progress monitoring, plan evaluation, and plan revision--capabilities increasingly seen as critical for independent and effective learning.

- **Passive learning creates motivational and "crowd control" problems.** Didactic or lecture instruction produces the same behaviors in adults and children, American and foreign. One researcher has described this pattern as a "waiting-it-out" posture: students sit impassively, gaze far away, feet dangling, investing minimal attention and involvement—behavior that one might observe in other waiting situations, such as when a bus is late or during lectures. Depending on the culture, students' ages and their objectives in the learning situation, a waiting-it-out stance often translates into restlessness, behaviors designed to break the monotony—in other words, into "discipline" and crowd control problems.

- **Passive learning encourages "veneers of accomplishment" by learners.** Passive learning places a premium on the ability of the learner to "reproduce" the Word. This translates into sounding and testing "right" within the school system, but often without real learning—into what has been called the "veneer of accomplishment." Students learn new ways of talking, new ways of legitimizing themselves, and new ways of presenting themselves as being in league with the school system. There are changes in linguistic repertoire and discourse skills, but not in behavior.

Learning is the strengthening of bonds between stimuli and correct response

The third assumption is that *learning is the strengthening of bonds between stimuli and correct responses*. American education reflects a behaviorist theory of learning—a view that conceives of learning as the strengthening of bonds between stimuli and the learner's responses to those stimuli. This psychological theory led to the breakdown of complex tasks and ideas into components, subtasks, and items that could be separately trained. The result is fractionation, or splitting into pieces: having to learn disconnected subroutines, items, and subskills, without an understanding of the larger context into which they fit and which give them meaning. We now know that fractionated programs make it almost impossible for individuals to acquire and retain information; this is best done by actively participating in holistic, complex, meaningful environments organized around long-term goals. *Human beings*—even the small child—*are quintessentially sense-making, meaning-creating, problem solving animals*. Fractionated and decontextualized instruction fails to mobilize this powerful property of human beings in the service of learning.

Learners are blank slates onto which knowledge is inscribed

The fourth assumption is that *learners are blank slates onto which knowledge is inscribed*. The transmission image of teaching and learning carries with it a view that learners, as initiates, come fresh to what is being taught. However, the evidence shows that learners carry into the learning situation conceptions and constructs that they have acquired elsewhere. In other words, the teaching challenge is not to write on a clean slate. It is to confirm, disconfirm, modify, replace, and add to what is already written there.

The time devoted to a lesson on a particular topic hardly suffices to surface, let alone change, the ideas and assumptions that individuals bring to the lesson. 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 make mistakes that arise from undetected ideas that they brought to the lesson. Or they can play back memorized knowledge and conceptions but return to their own ideas when confronted with unfamiliar questions or non-routine problems.

Skills and knowledge should be acquired independently

The fifth and last assumption is that *to be transferable to new situations, skills and knowledge should be acquired independent of their contexts of use*. This assumption is often talked about as "decontextualized learning," valued because extracting knowledge from the particulars of context is the presumed condition for making knowledge available for *general* application in all situations. Schooling reflects these ideas at a broad organizational level, as it separates children from the contexts of their own and their families' daily lives. At a more specific level, classroom tests put the principle to work: they serve as the measure of individual, "out of context" success, for the test taker must rely on memory alone and may not use books, classmates, or other resources for information. Context, however, turns out to be critical for understanding and thus for learning. *We are back to the issue of meaning-making and sense making*, discussed earlier. The importance of context lies in the meaning that it gives to learning.

Designing Effective Learning Environments: Cognitive Apprenticeships

How do we design more effective learning environments? In tackling this problem, cognitive scientists have been drawing on a wide array of historical, research, and experiential knowledge—for example, on the ideas of nineteenth century educators, such as Francis Parker, the founder of progressive education in the United States, and John Dewey; on analyses of the spectacular learning of the very young child; on analyses of how traditional, Third World apprenticeship systems work; and on their reflections about what happens when they, as teachers themselves, try to create different learning environments. The fruits of this work are being called models of "cognitive apprenticeship" (Collins, Brown, and Newman, 1989).

Cognitive apprenticeships focus on learning-through-guided-experience, but emphasize cognitive, rather than physical, skills and processes. Traditional apprenticeships—for example, in tailoring, weaving, or brick-laying, teach skills that are "external" in the sense that they can literally be seen. This makes them available to students and teachers for observation, comment, refinement, and correction. This ability to see the relevant skills, procedures, and resulting products helps the student build a conceptual model of the complex target skill and to envision his or her ultimate performance goal. And the relatively transparent relationship, at all stages of production, between process and product facilitates the learner's recognition and diagnosis of errors, upon which the early development of self-correction skills depends.

Applying apprenticeship methods to skills that are not particularly visually observable—in other words, to largely cognitive skills—means that ways have to be found to "externalize" processes that are usually carried out internally. As most subjects are taught and learned in school, teachers cannot make fine adjustments in students' application of skill and knowledge to problems and tasks, because they have no access to the relevant cognitive processes. By the same token, students do not usually have access to the cognitive problem solving processes of instructors as a basis for learning through observation and mimicry.

Keeping this challenge in mind, Collins et al. created a model of cognitive apprenticeship. The model has four building blocks—what Collins et al. call "content," "methods," "sequence," and "sociology." It is these pieces *working together* that define an effective learning situation. Many of the ideas here are not new, but together they frame an image of very different classrooms, roles for teachers, and roles for students.

Cognitive apprenticeship addresses what is learned ("content"). However, its primary implications are for how teaching and learning occur: for the role of the teacher; for the design of the social, technological, and motivational environment for learning; and for the "staging" of learning challenges.

How Do Cognitive Apprenticeship Ideas Fit Current Policies and Programs?

How do these ideas fit into policy discussions about different models of integrating academic and vocational education, work-based apprenticeship (work-based learning), technical preparation ("tech prep") and 2+2 programs, and cooperative education?

Relationship to models for integrating academic and vocational education

The models thus far identified (Grubb and Plihal, 1990) differ primarily in their organizational arrangements and the depth and breadth of the integration of academic and vocational education. The curricular ("what") and pedagogic ("how") principles of cognitive apprenticeship are not only consistent with integration ideas. *We propose that they in fact rigorously define what a vocationally and academically integrated learning environment should look like.*

The policy motivation for integrating academic and vocational education is to use the best of vocational education pedagogy (the "how" of teaching) for learning academic material and for infusing vocational curricula with much more rigorous academic content. Good vocational education is more apt to use some of the methods (such as modeling, coaching, or scaffolding and fading) and sociology (such as contextualized and co-operative learning) of cognitive apprenticeship than good academic education. However, even when vocational education picks up pedagogic elements of cognitive apprenticeship, it is generally weaker on the content side—in academic knowledge and the higher order cognitive skills (the heuristic strategies, cognitive management strategies, and learning strategies). The principles of cognitive apprenticeship *systematically* preserve and integrate the best of academic and vocational education into a single model that can be used to teach mathematics or interior design, the main difference between the two reside in one element: domain knowledge. It thus can function as the grounded curricular and pedagogic model for integrating the two.

Work-based apprenticeship (work-based learning)

"Workplace apprenticeship" presumes: (1) an apprenticeship learning situation, and (2) the workplace as the locus of that situation. *These represent two separable assumptions;* one does not logically entail the other.

A cognitive apprenticeship strategy should be able to deliver powerful learning relevant to the workplace in a school-based environment. Given the sobering obstacles that are emerging as we gain experience with work-based apprenticeships, the option of school-based cognitive apprenticeships must be considered. For example, evidence on informal on-the-job training and on employers' training investment patterns suggest that workplaces are not good learning places for the young and the less educated.

First, cognitive apprenticeship is a grounded model for effective learning. In that sense it is as relevant to work-based apprenticeships as to school-based programs. Second, the principles of cognitive apprenticeship were derived from *school-based* programs that had consciously tried to implement the implications of cognitive science for learning. Thus, the design has been implemented in schools, indicating that there is nothing *logically* incompatible between the design and schools. Third, cognitive apprenticeship is designed for or is compatible with learning the generic skill requirements of the modern workplace, as these are now understood. And finally, the press of the workplace—"keeping the line going"—and the motivating feedback of being engaged in actual economic activity probably mean that in work-based apprenticeship the apprentice learns better and faster whatever the workplace demands he or she learn. However, unless work-based apprenticeships are deliberately designed for doing-based *learning*, a work-based course of study will probably have potentially serious holes and inefficiencies.

Technical preparation ("tech prep") and 2+2 programs

In federal law technical preparation ("tech prep") denotes a four-year curriculum, starting in the last two years of high school and leading to an associate degree in a technical field of work—hence the term "2+2." The courses are expected to integrate academic and vocational content and to be vertically integrated (coordinated) across the four years and across high schools and community colleges. These programs are like some of the academic/vocational integration models, except that they are expected to span both high schools and community colleges. The relationships between these programs and cognitive apprenticeship ideas are the same as those between cognitive apprenticeship and the academic/vocational integration models discussed earlier.

Cooperative education

Cooperative education (co-op) deliberately alters the work process to facilitate learning and is more school-based than work-based apprenticeship. The student's classroom instructor arranges job placements, writes a training plan detailing what each student is expected to learn on the job, and visits students' job sites to monitor the training. The students' job supervisors evaluate their performances in terms of training objectives. In theory, cognitive apprenticeship principles could be built into co-op programs. However, essentially co-op has to take the workplace as it finds it, fitting training plans around the uneven training skills of supervisors and supervisors' uneven (and often limited) authority to alter the work process to support learning.

In the Final Analysis: How Effective Is Cognitive Apprenticeship?

We do not yet know, especially if the question is whether cognitive apprenticeship is effective in routine, as opposed to hot house (intense, concentrated), learning situations. However, the ideas do not come out of nowhere; in fact, they are unusually well grounded.

Cognitive apprenticeship strategies build on traditional apprenticeship, a tested, cross-cultural strategy for effectively acquiring visually observable skills. They build on and incorporate the ideas and findings of a community of serious thinkers and researchers, from John Dewey to today's cognitive scientists.

However, learning situations that reflect cognitive apprenticeship principles are not abundant. Extending them requires dealing with institutional, curricular, pedagogic, evaluation, and professional training issues. The model itself will change as we gain experience with it in the bruising real world of teaching and learning.

CHAPTER I.

Trouble in Paradise

Schools routinely and profoundly violate what we know about how people learn the most effectively and the conditions under which they apply their knowledge appropriately to new situations. Programs closer to what we now believe to be effective learning situations are rare; features of them are more apt to be found in very high quality vocational or magnet schools—schools that also ease the transition from school to work.

A powerful knowledge base, known as "cognitive science,"[1] is the basis for this discussion. Its findings have been used primarily to critique elementary and secondary education. However, despite the rhetoric about their differences, the nation's educational and training systems do not differ particularly in their teaching and learning strategies, and the limited success that they share arises partly from shared problems in how they structure learning. The common American experience with the public schools powerfully frames our ideas and models of what learning environments should look like, whether a seventh grade classroom, a college classroom, an adult literacy class, or a corporate training classroom. Thus, the educational problems of our elementary and secondary schools get reproduced even in training systems that we like to think of as non-traditional, such as training programs for disadvantaged adults.

There are several puzzles that force us to rethink teaching and learning, the following three being just examples.

- People do not predictably transfer what they learn in school to new situations—at least in any way that researchers have thus far been able to observe. However, the point of school is instruction in what can be used later.
- There are situations of "spectacular learning"—where the individual picks up knowledge and skills rapidly and with little apparent effort. For example, in the first five years of life the child learns spectacularly—acquiring concepts, language, motor skills, spatial and social skills with little explicit intervention or effort (Pea, 1989). However, in the school setting we see neither the speed nor the ease of learning that occurs outside school.
- Students of different ages and from different countries go into the same "waiting-it-out" behaviors in a standard lecture situation, but become deeply engaged in their tasks in collaborative projects.

What's going on here? Let's take a look.

1 Cognitive science is an interdisciplinary field that encompasses psychologists, linguists, anthropologists, computer scientists, philosophers, and neuroscientists. The word "cognitive" refers to perceiving and knowing, and cognitive science is the science of the mind. Cognitive scientists seek to understand perceiving, thinking, remembering, understanding language, learning, and other mental phenomena. Their research is very diverse, ranging from observing children learning mathematics or experienced workers handling the cognitive demands of their jobs, through programming computers to do complex problem solving, to analyzing the nature of meaning (Stillings et al, 1987).

CHAPTER II.

Five Assumptions About Learning—All Wrong

1. People Predictably Transfer Learning

We assume that the point of schooling is to prepare students for effective and responsible functioning in non-school settings, which include, but are not limited to, the workplace. Accepting this assumption means that we have to confront what is known as the "knowledge transfer problem." "Knowledge transfer" simply means the appropriate use in a new situation of concepts, skills, knowledge, and strategies acquired in another.

Research, extensive and spanning decades, shows that individuals do not predictably transfer knowledge in any of three situations where transfer should occur. They do not predictably transfer school knowledge to everyday practice (e.g., Pea, 1989; Lave, 1988a). They do not predictably transfer sound everyday practice to school endeavors, even when the former seems clearly relevant to the latter. They do not predictably transfer their learning across school subjects.

Transferring from school to outside of school

This transfer situation is at the heart of schooling. Usually the major claim for school-type instruction is its generality and power of transfer to situations beyond the classroom (Resnick, 1987). The fundamental question is whether knowledge, skills, and strategies acquired in formal education in fact get used appropriately in everyday practice.

- Students in college physics courses designed for physics majors can solve "book" problems in Newtonian mechanics by rote application of formulae. However, even after instruction, they revert to naive pre-Newtonian explanations of common physical situations to which their school learning is relevant (diSessa, 1983).

- Studies of expert radiologists, electronic troubleshooters, and lawyers all reveal a surprising lack of transfer of theoretical principles, processes, or skills learned in school to professional practice (Resnick, 1987). For example, Morris and Rouse (1985) found that extensive training in electronics and troubleshooting theories provided very little knowledge and fewer skills directly applicable to *performing* electronic troubleshooting.

- Dairy workers were highly flexible in the arithmetic strategies that they used in filling orders and making out bills. Students, however, when confronted with new practical arithmetic problems whose efficient solution required modifying school-learned procedural rules, continued inflexibly to apply these rules (Scribner and Fahrmeir, 1982).

Transferring from outside of school into school

People learn outside of school all the time. In fact, Piaget's point that intelligence is built out of interaction with the environment is really a point that learning opportunities are abundant. The question then is what people do with what they learn outside of school when they move into the school. Does sound, everyday practice get transferred (get used) in school learning? How does "incorrect" learning outside school affect "correct" learning inside school?

- Dairy workers, although almost errorless in their use of practical arithmetic at work, performed badly on arithmetic tests with problems like those encountered in their jobs (Scribner and Fahrmeir, 1982).

- Brazilian street vendor children used informally developed counting procedures to successfully solve 98 percent of their marketplace transactions, such as calculating total costs and change. When presented with the same transactions in formal word arithmetic problems that provided some descriptive context, the children correctly solved 74 percent of the problems. However, their success rate dropped to 37 percent when asked to solve the same types of problems when these were presented as mathematical operations without descriptive context (Carraher, Carraher, and Schliemann, 1985).

- Herndon (1971, as quoted in Lave, 1988a), a middle school teacher working with students who had failed in mainstream classrooms, discovered that one of his students had a well-paid, regular job scoring for a bowling league. The work demanded fast, accurate, complicated arithmetic.

> *"...eight bowling scores at once. Adding quickly, not making any mistakes (for no one was going to put up with errors), following the rather complicated process of scoring in the game of bowling. Get a spare, score ten plus whatever you get on the next ball, score a strike, then ten plus whatever you get on the next two balls; imagine the man gets three strikes in a row and two spares and you are the scorer, plus you are dealing with seven other guys all striking or sparing or neither one.*
>
> *I figured I had this particular ... kid now. Back in eighth period I lectured him on how smart he was to be a league scorer in bowling. I pried admissions from the other boys, about how they had paper routes and made change. I made the girls confess that when they went to buy stuff they didn't have any difficulty deciding if those shoes cost $10.95 or whether it meant $109.50 or whether it meant $1.09 or how much change they'd get back from a twenty. Naturally I then handed out bowling-score problems, and naturally everyone could choose which ones they wanted to solve, and naturally the result was that all the ... kids immediately rushed me yelling 'Is this right? I don't know how to do it! What's the answer? This ain't right, is it?' and 'What's my grade?' The girls who bought shoes for $10.95 with a $20 bill came up with $400.15 for change and wanted to know if that was right? The brilliant league scorer couldn't decide whether two strikes and a third frame of eight amounted to eighteen or twenty-eight or whether it was one hundred and eight and a half."*

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- Lave (1988a) reports a very low relationship between success in arithmetic tests and correct solutions to best-buy calculations in the supermarket. An analysis of the data shows discontinuities in performances, errors, and procedures between the supermarket on one hand and test activities on the other, although the arithmetic problems are formally similar and the persons solving them the same.

Transferring between disciplines within school

Do the skills, strategies, concepts, and other knowledge developed within one discipline get transferred across traditional curricular divisions?

- At the turn of the century Thorndike conducted many studies of the transfer of learning from one school subject to another. At the time students commonly learned Latin and mathematics, " ... not so much for its utility, as for its alleged promotion of 'mental discipline' for learning about other curricular topics. The negative findings ... devastated the discipline hypothesis" (Pea, 1989, p.2).

  Training on one version of a logical problem has little, if any, effect on solving an isomorphic version, differently represented (Hayes and Simon, 1977), and teaching children to use general context-independent cognitive strategies has no clear benefits outside the specific domains in which they are taught (Pressley, Snyder, and Cariglia-Bull, 1987, as cited in Perkins and Salomon, 1989.)

Summary

Cognitive experts agree that the conditions for transfer are not fully understood. We know that people undeniably and routinely apply skills such as reading, writing, and arithmetic to new situations with some success. True, these skills are used most effectively in well-understood content domains. For example, readers get more out of their reading when they know something about the domain in which they are reading than when they do not. Nonetheless, skills such as reading do let us "enter" unfamiliar content areas—we do use these skills in new situations, and they do help us.

At the same time, we also keep finding lack of transfer. We now know that certain practices of schools impede learning. Flawed learning has to translate into flawed transfer. At the same time, better learning does not logically imply better transfer—it may be a necessary, but not sufficient condition for transfer. Let's look now at the deeply embedded educational practices that inadvertently create learning problems and thus transfer problems.

2. Learners Are Best Seen As Passive Vessels Into Which Knowledge Is Poured

Think about a typical schoolroom—or a Congressional hearing, or a corporate training session. The teacher—or "expert"—faces the learners, in the role of knowledge source. The learner is the passive receiver of wisdom—a glass into which water is poured.

This instructional arrangement comes out of an implicit assumption about the basic purpose of education: the transmission of the society's culture from one generation to the next. The concept of transmission implies a one-way flow from the adult members of the society to the society's entering members (the young) (Lave, 1988)—or from the expert to the novice.

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In fact, schooling is often talked about as the transmission of "canonical" knowledge. "Canonical" derives from "canon," defined in *Webster's Ninth New Collegiate Dictionary* (1987) as: (1) a regulation or dogma decreed by a church council; (2) the most solemn and unvarying part of the Mass; (3) an authoritative list of books accepted as Holy Scripture.

Education as canonical transmission thus becomes the conveying of what experts know to be true, rather than as a process of inquiry, discovery, and wonder. This view of education leads naturally to the student as receiver of the Word, to a lecture mode of teaching, and to the teacher as the controller of the process. These assumptions and their representation in educational practice contradict what we know about how people learn the most effectively.

Passive learning reduces or removes chances for exploration, discovery, and invention

Passive learning means that learners do not interact with problems and content and thus do not get the experiential feedback so key to learning. The student needs chances to engage in choice, judgment, control processes, problem formulation; he/she needs the chance to make mistakes. We have an adage in our culture, "Experience is the best teacher." In other words, you learn when you do, a popular observation borne out by the research. Although not sufficient for effective learning, doing is necessary.

However, the school often breaks up what is to be learned into small pieces and small steps—into subskills. This strategy has multiple origins, but it is certainly consistent with the idea that the point of school is to transmit a body of knowledge more easily digested in bite-size pieces. Fragmented and highly delineated knowledge leaves virtually no room for learner-initiated exploration, invention, and construction that the rapidly learning small child engages in constantly. The result is that, for example, in mathematics students come to regard mathematics as something received, not discovered, and as a body of knowledge, rather than as a form of activity, argumentation, and social discourse.

Passive learning places control over learning in the teacher's, not the learner's, hands

Passive learning creates learners dependent on teachers for guidance and feedback, thus undercutting the development of confidence in one's ability to learn, initiative, and cognitive executive skills.

Recall Herndon's students. They were asked to solve school math problems like ones that they had mastered outside of school. The problems were even presented in contexts the same as those outside of school which they had mastered. Their responses revealed that they had no sense of control over school problems. They guessed wildly, ran to Herndon for confirmation and help, and showed no confidence that their non-school experiences could help them.

Recall the Brazilian street vendor children. The researchers found that when the children tried to work school math problems, they did not check the sensibleness of their answers by relating them back to the initial problem. Although virtually errorless in their street math activities, they came up with results for school math problems as preposterous as those of Herndon's students (Carraher et al., 1985).

In the study of supermarket shoppers' use of arithmetic, the researchers assessed the shoppers' command of structurally similar school math problems. The shoppers spoke with self-deprecation about not having studied math for a long time. Common requests were "May I rewrite problems?" and "Should I ... ?"

Lave (1988, pp.69-70) clarifies what is happening here. Individuals experience themselves as both subjects and objects in the world. In the supermarket, for example, people experience themselves "as in control of their activities, interacting with the

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setting, generating problems in relation with the setting and controlling problem solving processes ... In contrast, school ... create[s] contexts in which children ... experience themselves as objects, with no control over problems or choice about problem solving processes." In sum, control in the teachers' hands, not the students', undercuts students' trust in their own sense-making abilities.

As important, passive learning undercuts the development of a particular set of higher-order cognitive skills, the "cognitive self-management" or "executive thinking" skills. These include goal setting, strategic planning, checking for accurate plan execution, goal-progress monitoring, plan evaluation, and plan revision (Pea, 1989).

When someone is an independent, directed, and effective learner, we now know that we are seeing a learner with these skills. However, as Pea (1989) observes, passive learning is disastrous for developing them. " ... [W]e know from classroom studies of reading, writing, math, and science instruction ... that the fundamental *executive processes* for controlling thinking and learning processes are under the teacher's control, not the student's." To anticipate a later section of this paper, these processes get developed when the learning situation is structured to *pass on* control processes from teacher to student. The teacher gradually removes the prompts and support that students need initially as they begin to show the ability to handle these processes autonomously.

Passive learning creates motivational and "crowd control" problems

Jordan (1987) describes a Mexican public health training program designed to improve the practice of Mayan midwives. Her analysis spotlights behaviors that American teachers constantly complain about in their students.

> *"For the first course, which dealt primarily with family planning, the midwives were assembled in the lecture room of the regional hospital. In this course, as in most others, most of the teaching activities consist of imparting straight didactic [instructive] material, using mini-lecture format. The staff follow a kind of lesson plan which mandates presentations of thirty to sixty minutes' duration.*
>
> *Any time one of these lectures begins, a series of significant behaviors on the part of the midwives can be observed. As the lecturer launches into her or his spiel ... , the midwives shift into their 'waiting-it-out' posture: they sit impassively, gaze far away, feet dangling, obviously tuned out. This is behavior that one might also observe in other waiting situations, such as when a bus is late or during sermons in church" (p.3).*
>
> *Observations of American third graders during their math lessons reveal similar behaviors.*
>
> *" ... the children were deeply engaged in math work during drill and practice time [where they sat together at a table and interacted to solve the problems], while they invested minimal attention and involvement in ongoing activity during the teacher's instruction sessions. During the three weeks [of observation] the children gave no evidence of having adopted any of the specific strategies demonstrated by the teacher during general instruction time" (Hass, n.d., as cited in Lave et al., 1988).*

Again, as teachers know so well, motivational problems end up as crowd control problems. Farnham-Diggory (1990) contrasts the behaviors of different groups of school children at a Metropolitan Museum display of Ice Age art and artifacts. The differences are attributable to the children's involvement with the show.

Most of the school groups were moved from one exhibit to the next, pausing before each to hear a guide's or teacher's lecture. Since the children were bunched in front of a exhibit, they could not all hear the lecture, and, even when they could, they lacked understanding of the time frames involved or the archaeological significance of bits of bone. Groups were therefore restless and crowd control became the teacher's primary concern.

> *"One [exhibit] hallway was raised, and each group discovered that it could make booming noises by tramping hard over the hollow areas—booms that could never be proved to have been produced by an particular pair of feet. This seemed to provide the main entertainment of the day" (p.88).*

However, Farnham-Diggory observed one junior high school class that behaved very differently.

> *"I became aware of these children when one or two of them materialized beside me, studying an exhibit with a quiet intensity that equaled my own and making notes and drawings ... Eventually, I discovered that the adult who offered them advice from time to time was their teacher ... [who], however, was enjoying the exhibit on a relatively uninterrupted basis, with absolutely no concern for discipline or control.*
>
> *The junior high students had packets of worksheets, which contained questions about issues and problems that the students had come to the exhibit to resolve. Some questions were factual, but most required inference and thought. The students had to figure out for themselves where and what the evidence would be concerning particular questions" (pp.88-89).*

Passive learning encourages "veneers of accomplishment" by learners

Passive learning places a premium on the ability of the learner to "reproduce" the Word. This translates into sounding and testing "right" within the school system. but often without real learning—into what has been called the "veneer of accomplishment" (Lave et al., 1988). Again, Jordan's (1987) description of Mayan midwives' training and learning illuminates basic truths about the learning—and the testing—of American students.

> *"What I observed in working with midwives who had attended the training course is that they had learned how to talk to representatives of the official health care system. They had learned what kinds of things were 'good' and what kinds of things were 'bad.' They had become exposed to an ideology which they knew was powerful, which commanded resources and authority, and to which they could now better accommodate. Specifically, they had learned new ways of talking, new ways of legitimizing themselves, new ways of presenting themselves as being in league with this powerful system, which, however, had little impact on their daily practice. I believe that the major effect of training courses of the kind I have described is a new facility to talk in the language of biomedicine ...*
>
> *I would suggest, then, that current teaching methods produce only minimal changes in the behavior of trainees, while, at the same time, providing new resources for talking about what they do. In particular, midwives learn how to converse appropriately with supervisory medical personnel, so that when the public health nurse visits to check on them, they can give all of the appropriate responses to her questions. Training courses may actually serve to provide the semblance of medical legitimization through the bits and pieces of exotic medical gadgetry and terminology which midwives pick up without concomitant change in behavior. The new knowledge is not incorporated in midwives' behavioral repertoire; it is verbally, but not behaviorally fixed ...*
>
> *What is measured [to determine the effectiveness of these courses] ... is the degree to which midwives are able to reproduce definitions, lists, and abstract concepts. In other words, if these tests measure anything at all, they measure*

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changes in linguistic repertoire and changes in discourse skills [not changes in behavior]" (pp.10-12).

What Jordan describes here is what, in the case of American students, has been called the "veneer of accomplishment." Students *look like* they grasp what teachers and schools want them to learn—but, in fact, do not.

Again, Hass' American third graders look like Jordan's Mayan midwives. He observed that in math lessons the students got much practice in problem solving methods that they had brought into the classroom with them—methods that were not being taught and that were not supposed to be used. The children used these methods to produce right answers, which the teacher took as evidence of their having grasped the formal procedures that she was teaching them. In fact, all that had happened was the *appearance* of learning.

Lave, Smith, and Butler (1988) cite Resnick's (1986) observations that school learners have reasonably correct calculational rules and, in the classroom, learn rules for manipulating the syntax of symbolic notation systems. However, they fail to learn the meaning of symbols and the principles by which they represent quantity and its permissible constrained transformations. In other words, wrong answers are likely to look right, while at the same time conceptual errors betray a lack of mathematical understanding.

3. Learning is the Strengthening of Bonds Between Stimuli and Correct Responses

American education reflects a behaviorist theory of learning—a view that conceives of learning as the strengthening of bonds between stimuli and the learner's responses to those stimuli. For our purposes this psychological theory had two major effects. It led to the breakdown of complex tasks and ideas into components, subtasks, and items that could be separately trained. It also led to the counting of the number of correct responses to items and on subtasks, a perspective that ended up in psychometrically elegant tests considered the scientific way to measure achievement.

The result is fractionation, or splitting into pieces: having to learn disconnected subroutines, items, and subskills without an understanding of the larger context into which they fit and which give them meaning. As Farnham-Diggory (1990) notes:

> *"It is now known that fractionated programs make it almost impossible for children to acquire and retain information. Fractionated instruction maximizes forgetting, inattention, and passivity. Both children and adults acquire knowledge from active participation in holistic, complex, meaningful environments organized around long-term goals. Today's school programs could hardly have been better designed to prevent a child's natural learning system from operating" (p.146).*

The "child's natural learning system." This phrase goes to the heart of why the usual school programs do not meet their own learning objectives well. *Human beings*—even the small child—*are quintessentially sense-making, problem solving animals.* Think of young children: "why" is a hallmark of their talk. As a species, we *wonder*, we are *curious*, we want to *understand*. Pechman (1990) talks about the child as meaning maker. Fractionated and decontextualized instruction fails to mobilize this powerful property of human beings in the service of learning.

The point about "subtasks" is not that learners do not have to do simple operations. Studies of traditional apprenticeships in tailoring show that novices start with simple tasks. However, they conduct simple tasks in the context of being able to observe the masters' and journeymen's execution of the target process: complex tailoring, which involves the integration of different but interrelated subskills.

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Observation lets learners develop a conceptual model or cognitive map of the target task. This model gives learners an advanced "organizer" for their initial attempts to execute a complex skill; it provides an interpretive structure for making sense of the feedback and corrections from the master; it provides an internalized guide for the period of relatively independent practice by successive approximation (Collins, Brown, and Newman, 1989).

4. Learners Are Blank Slates On Which Knowledge Is Inscribed

The transmission image of teaching and learning carries with it a view that learners, as initiates, come new to what is being taught. However, the evidence shows that learners carry into the learning situation conceptions and constructs that they have acquired elsewhere. In other words, the teaching challenge is not to write on a clean slate. It is to confirm, disconfirm, modify, replace, and add to what is already written there.

The time devoted to a lesson on a particular topic hardly suffices to surface, let alone change, the ideas and assumptions that individuals bring to the lesson. 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 make mistakes that arise from undetected ideas that they brought to the lesson. Or they can play back memorized canonical knowledge and conceptions but return to their own ideas when confronted with unfamiliar questions or non-routine problems. As noted earlier, 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 (Raizen, 1989).

The literature on science learning gives many examples of how the learner's prior knowledge and conceptions affect new learning. As Raizen points out (1989), 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 may be personal—i.e., constructed out of their interpretations of naive experience and coherent in their own terms. Or they may come from partially understood or inappropriately applied school learning.

For example, White (1983), in diagnosing sources of students' difficulty in understanding Newtonian dynamics, found that students used varying and often inconsistent ideas in solving force and motion problems. These ideas included faulty beliefs about force and motion. Suppose a ball is hit and starts to roll and then is hit again in a different direction. When asked where the ball will now go, people with no physics background will usually answer that the ball will go in the direction of the last hit (diSessa, 1982).

> *"They appear to be neglecting the momentum of the ball when they are giving their answer ... Living in a world with friction could be one source of this error. In a frictional environment, objects in motion slow down unless a force is constantly being applied to them. The effect is that usually, in everyday life, when one [kicks a ball a second time] the [ball] is in the stopped state. Further, in the few instances where one hits something that is moving, the sequence of events is usually too rapid for analysis. It is likely that these factors result in [beliefs] such as things go in the direction that you hit them and that the same size [kick] will always produce the same resulting speed of motion. (White, 1983, pp.57-58)*

Students also made errors because they relied on partially understood examples from physics classes. Finally, they applied their knowledge of scaler arithmetic to vector arithmetic, the properties of scaler arithmetic not always transferring to vector arithmetic.

5. To Be Transferable to New Situations, Skills And Knowledge Should Be Acquired Independent of Their Contexts of Use

This assumption is often talked about as "decontextualized learning." Lave (1988) describes how it works and why it is valued.

> *"Extraction of knowledge from the particulars of experience, of activity from its context, is the [presumed] condition for making knowledge available for general application in all situations. Schooling reflects these ideas at a broad organizational level, as it separates children from the contexts of their own and their families' daily lives. At a more specific level, classroom tests put the principle to work: they serve as the measure of individual, 'out of context' success, for the test taker must rely on memory alone and may not use books, classmates, or other resources for information."*

Context, however, turns out to be critical for understanding and thus for learning. *We are back to the issue of meaning-making and sense-making,* discussed earlier. The importance of context lies in the meaning that it gives to learning. Brown, Collins, and Duguid (1989) make this point, first about language, and then about all knowledge.

> *" ... words and sentences are not islands, entire unto themselves. ... Experienced readers implicitly understand that words are situated. They, therefore, ask for the rest of the sentence or the context before committing themselves to an interpretation of a word ... All knowledge is, we believe, like language. Its constituent parts index the world and so are inextricably a product of the activity and situations in which they are produced ...*
>
> *... we should abandon any notion that [concepts] are abstract, self-contained entities. Instead, it may be more useful to consider conceptual knowledge as ... similar to a set of tools. Tools share several significant features with knowledge: They can only be fully understood through use ... " (p.33).*

Resnick (1987), agreeing with Lave's description of school learning, contrasts it with thinking, problem solving, learning, and knowledge-using outside of school.

> *"The third contrast is between symbol manipulation in school versus reasoning about things and situations that make sense to people outside of school. School learning is mostly symbol-based, to such an extent that connections to the things being symbolized are often lost. 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, there is a very large tendency for symbolic activities to become detached from any meaningful context. School and school-like learning then becomes a matter of learning rules and saying or writing things according to the rules. This focus on symbols detached from their referents creates difficulties even for school learning itself."*

The idea of context in fact is very simple, although designing contexts that optimally support learning goals is neither simple nor easy. Our best teachers in our best schools already instinctively "contextualize" even the most "academic" of subjects. For example, a fifth grade teacher in a McLean, Virginia school introduces the study of economic concepts by setting up a simulation of a small economy within the classroom. The point of the simulation is to give her students experience with—meaningful context for—fundamental economic concepts such as competition, monopolies, bankruptcy, rents, or taxation. Reading a discussion of markets, sellers, and competition in a textbook means much more to the student who, just the previous day, waged a price war with a seatmate to corner the market on hot dog sales. "Taxation" means much more when another seatmate who represented government has bought the classroom door, forcing everyone to pay taxes every time they need to go in or out of the room—for example, to get water to boil their hot dogs.

The research supports the power of learning in context, as opposed to out of context. As noted earlier, Brazilian street vendor children solved context-embedded problems much more easily than ones without a context, the difference in correct answers being 74 percent for the former type and 37 percent for the latter type (Carraher et al., 1985). Sticht (1989) found that marginally literate adults in a job-related reading program made twice the gain in job-related reading than they did in general reading—that is, they did better when a meaningful context was provided for the text.

Students at McMaster University School of Medicine in Ontario start immediately with clinical problems, meeting in tutorial groups with a tutor who acts as a resource person. The tutorials are organized around major biomedical problems that cannot be solved without understanding physical, biological, and behavioral principles, how to collect data, and how to evaluate evidence. The students have the responsibility to determine, with faculty help, what they need to know to solve the problem, and how to find what they need.

Maastricht, a medical school in the Netherlands, uses an approach similar to McMaster's. Since the Dutch government assigns students to medical school by lottery, we can compare the effects of contextualized, problem-centered medical training with training that uses a traditional lecture approach. On average, Maastricht students score higher on tests of anatomy (in which they have had no formal instruction) than residents trained in traditional medical schools. After seven years in school 88 percent of Maastricht's 1974 class had received diplomas, versus 21 percent of students in other schools (Albert Shanker, "Here We Stand," *New York Times*, July 8, 1990).

At a macro level, a random assignment experiment with 20,000 students and 100 magnet-vocational schools and programs in New York City shows that students in magnet schools and programs perform better than their counterparts in the zoned comprehensive schools (Crain, et al., in preparation). Some of these effects are probably attributable to what Hill et al. (1990) call the effects of "focus."[2] Some, however, seem attributable to the fact that these schools are organized around what real people do in the real world—in a sense, everything that goes on in the school is contextualized.

Below we address what "context" means in the design of powerful learning environments. To interpret it as making learning "relevant," as that term came to be used in education in the 1960s, is to miss the point entirely.

Summary

As we look at the five mistakes that we make in teaching and learning, it's no wonder that we find no predictable transfer to new situations. Knowledge and procedures not initially well learned and understood will not transfer appropriately to new situations. In a passive learning regime, students do not gain control over their learning, let alone over what is to be learned. The ideas that they bring to the learning situation are not made accessible to them for re-examination. They are asked to learn in decontextualized and fragmented ways that destroy sense-making.

2 The authors identify two efforts of focus. First, magnet schools have clear, uncomplicated missions centered on the experiences that the school intends to provide its students and on the ways it intends to influence its students' performance, attitudes, and behavior. Second, focus schools are strong organizations with a capacity to initiate action in pursuit of their missions, to sustain themselves over time, to solve their own problems, and to manage their external affairs.

CHAPTER III.

Designing Effective Learning Environments: Early Inspirations

How do we design more effective learning environments? In the last decade cognitive scientists have been addressing this question in specific subjects, such as reading and mathematics, and as general learning principles. The fruits of this work are being called models of "cognitive apprenticeship," described in the next section.

In tackling the problem of more effective learning environments, cognitive scientists have been drawing on a wide array of historical, research, and experiential knowledge—for example, on their understanding of how the young child learns, on descriptions of how traditional apprenticeship systems work, and on their reflections about what happens when they, as teachers themselves, try to create different learning environments.

Nineteenth Century Educational Ideas

As Farnham-Diggory notes (1990), early precursors were the educational ideas of Francis Parker, the nineteenth century founder of progressive education in the United States, who in turn drew on the ideas of Jean-Jacques Rousseau and his disciples, Johann Heinrich Pestalozzi and Friedrich Froebel. Parker threw out the traditional curriculum and replaced it with educational projects and experiences meaningful to children.

Another source was John Dewey, who built on Parker's ideas. The curriculum at the laboratory school that Dewey founded at the University of Chicago had three principles:

- instruction must focus on the development of the student's mind, not on blocks of subject matter;
- instruction must be integrated and project-oriented, not divided into small units (such as forty minutes of English, forty minutes of mathematics); and
- through the years of schooling, the progression of the curriculum must be from practical experiences (such as planting a garden) to formal subjects (such as botany) to integrated studies (such as the place of botany in the natural sciences).

The Dewey curriculum was organized around occupations: gardening, work with textiles, scholarly research, producing artistic works, manufacturing, and exploring unknown territories. The study of occupations permitted children to learn in ways that were natural and interesting to them. Occupations always involved doing something. They engaged and developed the child's motor skills and "hands-on" modes of learning. They involved making observations, analyzing, investigating, quantifying, and making predictions, thus developing the child's scientific skills. They involved other people and thus encouraged the child's social skills and interests. They required the exchange of ideas, thus providing opportunities for training in communication.

The Child As Spectacular Learner

Analyses of the conditions for spectacular learning of the young child gave some clues for designing cognitive apprenticeships (Bransford et al., 1985; Pea, 1989).

- Learning takes place in context. Children learn during the first five years in the midst of culturally meaningful, ongoing activities and receive immediate feedback on the success of their actions.

- Learning is often effectively mediated. Parents, friends, and peers not only serve as models for imitative learning, but help the children learn by providing structure to and connections between their experiences. These mediators highlight information in the situation that will particularly help the child to carry out a task. They let them take on "part" activities in the conduct of a whole task, such as mixing sugar and flour in the whole process of making a cake.

- Learning is functional. Context and mediation help give children an understanding of the functions of information for problem solving. Concepts and skills are acquired as tools with a range of purposes.

- The functions of new knowledge are not only shown, but often explicitly stated—the need for and purpose of the learning are explained.

Traditional Apprenticeship Learning

Another source of cognitive apprenticeship ideas is watching how individuals learn in traditional apprenticeships, including informal on-the-job training in American companies (Lave, in preparation; Jordan, 1987; Scribner and Sachs, 1990). One will see similarities between traditional apprenticeship and the young child's "spectacular" learning.

What does traditional apprenticeship look like? In her studies of Vai and Gola apprentice tailors, Lave noted that the tailoring curriculum arranges opportunities *for* practice, whereas school curricula tend to be a specification *of* practice (Lave et al., 1988). She found that the apprentices learned tailoring through a combination of observation, coaching, and practice.

> *"In this sequence of activities, the apprentice repeatedly observes the master executing (or modeling) the target process, which usually involves a number of different but interrelated subskills. The apprentice then attempts to execute the process with guidance and help from the master (coaching). A key aspect of coaching is the provision of scaffolding, which [simply means] the support, in the form of reminders and help, that the apprentice requires to approximate the execution of the entire composite of skills. Once the learner has a grasp of the target skills, the master reduces (or fades) his participation, providing only limited hints, refinements, and feedback to the learner, who practices by successively approximating smooth execution of the whole skill" (Collins, Brown, and Newman, 1989).*

Jordan (1987), relating her observations of apprenticing among Mayan midwives to Lave's of the Vai and Gola tailors, identifies several characteristics of traditional apprenticeship learning.

1. Apprenticeship is a way of life

Apprenticeship happens as a way of, and in the course of, daily life and may not be recognized as a teaching effort at all. In other words, there is likely to be almost no separation between the activities of daily living and learning of "professional" skills. Much of what child apprentices do is difficult to differentiate from play, since, particularly in traditional societies, children tend to play at serious work. Our western distinction between learning as an activity in its own right and playing does not prevail. Rather, the "apprentice" is exposed to a certain environment, participates in sets of activities, handles (plays) with certain kinds of artifacts, and is entrained into the sphere of specialist work the same way a child is into the home environment.

2. "Work" is the driving force

In apprenticeship the activities in which masters and students engage are driven by the requirements of the work to be accomplished. For example, pots need to be fired, a shawl needs to be woven, trousers need to be manufactured. The activities to which the apprentice is a witness and, by stages, a contributor, are organized around work to be done, and whatever teaching or learning may happen is coincidental to that overriding concern. As a consequence, the progressive mastering of tasks by the apprentice is appreciated not so much as a step towards a distant, symbolic goal (such as a certificate), but for its immediate use value. Apprentices are not so much "practicing for the real thing" as doing useful and necessary tasks. As Lave (in preparation) says, the master of a tailor shop who takes on an apprentice "mainly intends to provide himself with help on a variety of errands and small sewing tasks."

3. There is a temporal ordering of skill acquisition

Apprentices start with skills that are relatively easy and where mistakes are least costly. For example, as Lave points out, young tailor apprentices first experiment with parts of the production process that are least costly in terms of wasted materials. The apprentice's first assignments are sewing garments from pieces someone else has cut, not constructing it from start to finish. Only when the individual production processes are mastered is the entire production sequence put together. Similarly, among Zinacanteco Indian weavers major chunks of the garment construction process (e.g., dyeing, spinning, weaving, sewing) are learned in an order which reflects economic concerns, i.e., the relative cost of novice errors, rather than the standard order of production.

The concept of working from the "sidelines" of a complex task to its center stands in contrast to the ways that knowledge is usually transferred in formal schooling. In a formal classroom there is usually a (chrono)logically ordered sequence of things to be learned. The components are treated as equal in importance to one another, and it is assumed that they have to be acquired in a linear way—in other words, one after the other, rather than in "bundles."

4. Traditional apprenticeship learning focuses on bodily performance and embodied knowledge

When lectures are used to convey knowledge, the focus is on verbal and abstract knowledge. However, apprenticeship learning is the acquisition of bodily skills. It involves the ability *to do* rather than the ability to *talk about* something. Indeed, it may be impossible to elicit from people operating in this mode what they know how to do. The master is less likely to talk than to guide the hands, producing truly embodied knowledge. In the apprenticeship mode, acquisition of bodily skills is primary, while the verbalization of general principles is secondary, ill-developed and not well rehearsed.

5. Standards of performance and evaluation of competence are implicit

In fact, they are embedded in the work environment in which the novice participates. What constitutes expert execution of a task is obvious and observable in the master's performance. Judgements about the learner's competence emerge naturally and continuously in the context of the work being accomplished, rather than occurring as a specially marked event, such as a test. The success or failure of a task that has been performed is obvious and needs no commentary. To large extent, the person who judges the apprentice's performance is the apprentice himself or herself rather than the expert. The apprentice, having observed the work sequence many times, knows what remains to be learned. Moving on to the acquisition of the next skill may be up to the apprentice and largely under her or his own control, rather than that of the master's. In other words, the apprentice tends to "own the problem" of moving through the problem region and associated task space.

6. Teachers and teaching are largely invisible

In apprenticeship learning—and during informal on-the-job training in modern American workplaces—it looks as though little teaching is going on. Teaching simply does not occur as an identifiable activity and whatever instruction the apprentice receives originates, not from a teacher doing teaching, but from a weaver/tailor/stockroom worker doing his or her work that the apprentice observes.

Summary

In apprenticeship learning the apprentice is being inducted or entrained into what we later describe as a *community of expert practice*, whether the practice is that of tailoring, weaving, or whatever. Critical to this learning situation is that the "teacher" continuously engages in and is a master at the practice being learned. His or her performances constitute the standards of performance for the apprentice. A sloppy or incompetent "teacher" is at least as disastrous for an apprenticeship learning situation as for any standard classroom situation.

Clearly, traditional apprenticeships are not entirely transferable to a modern society. For example, practices such as tailoring or weaving are physically observable to the novice, and embodied knowledge—for example, the knowledge of the hand is important. However, many modern practices, whether mathematics, lawyering, or computer-based machining are either private events or only partly visible. Embodied knowledge is less important.

At the same time, traditional apprenticeships show what contextualized, effective learning looks like. Given the images of traditional apprenticeships, cognitive scientists have then been able to invent analogies appropriate for learning less visible practices.

Actual Trials

A final source for cognitive apprenticeship ideas is cognitive scientists' own efforts to design effective learning situations and curricula. These efforts span a number of subjects—for example, mathematics (e.g., Schoenfeld, 1985), physics (White, 1983 and 1984), reading (Palincsar and Brown, 1984 and 1989), writing (Scardamalia and Bereiter, 1985), and interior design (Stasz et al., 1990).

Let's look in some detail at Schoenfeld's design efforts in mathematics (1988). First, he identifies the learning objectives that he has for his students. He wants them:

- to understand that a major part of the mathematical enterprise consists of looking for and seeing connections, not simply 'getting answers.' From this perspective, solving a given problem does not represent the end of the mathematical enterprise, but a beginning; further steps include finding alternative solutions to the problem, generalizing the solution, relating it to other mathematics, and so on.

- to see that mathematics is something that they can generate by themselves, rather than a fixed body of facts and procedures that has been developed by others and they must memorize to master.

- to understand that both conjecture and proof are legitimate and related parts of the mathematical enterprise, and that the interplay of the two results in the development of one's own mathematical understandings (p.12).

To attain these objectives, he had to create a learning environment different than that of the standard mathematics class. Echoing traditional apprenticeships, he tried to create a "community of mathematical practice." The idea of a community of practice is quite simple. It refers to a social group that is organized around the performance of certain activities, where the performance is governed by shared rules, knowledge, standards, procedures, and so forth. A church group, with its priest and congregants, can be a community of practice. However, traditional apprenticeships, Schoenfeld's mathematics class, and Dewey's whole curriculum are organized around occupations. Thus, there can be communities of mathematicians, cooks, dentists, tailors, geographers, lawyers, electronic troubleshooters, writers, scientists, plumbers, computer programmers, or nurses.

> *"I try to create what might be called a microcosm of mathematical practice ... [T]he courses are a partially managed environment. I have a sense of what I want to achieve in them and of what problems will serve as fertile sources of ideas and explorations ... It is essential for me to help the students find fertile grounds for mathematical exploration ... But then it is equally essential for me gradually to remove myself from the process, moving to the side and prompting the group to resolve issues by itself. I remain engaged as a member of the community, making sure that the appropriate mathematical values are respected (Are we really sure? Is there a counterexample?). I refrain, however, from pronouncing what is right and what is wrong; I pose the issues and leave it (for as long as possible) for the class to resolve them ... At their own level the students are mathematicians, engaged in the practice of mathematical sense-making. They do mathematics, with the same sense of engagement and involvement. The difference is that boundaries of understanding that they challenge are the boundaries of their own understanding, rather than those of the mathematical community at large."* *(pp 12-13).*

Schoenfeld sees real similarities between his research work with professional mathematicians and the activities of his students in his mathematics class, suggesting that he has managed to create a learning environment that reproduces the environment of expert practice.

- "We work on substantial and meaningful problems. The few 'skill development' exercises in which we engage in either environment are chosen because we feel we need the skills ...

  There is a sense of commitment to the enterprise, and to the sense of values shared by the community.

- It's fun. There is pleasure in the involvement, in the progress being made, and in the results achieved" (p.14).

How well does Schoenfeld's design overcome the problems that pervade most classrooms? We have no independent assessment of the learning situation that he creates. However, we can look at what he thinks he has created in light of the problems discussed earlier.

The critique of the passive learning assumption pointed out that passive learning reduces or removes chances for exploration, discovery, and invention. Schoenfeld states: "I have a sense of what ... problems will serve as fertile sources of ideas and explorations ... It is essential for me to help the students find fertile grounds for mathematical exploration ... "

We noted that passive learning places control over learning in the teacher's, not the learner's, hands. Schoenfeld says: " ... it is equally essential for me gradually to remove myself from the process, moving to the side and prompting the group to resolve issues by itself. I remain engaged as a member of the community, making sure that the appropriate mathematical values are respected (Are we really sure? Is there a counterexample?). I refrain, however, from pronouncing what is right and what is wrong; I pose the issues and leave it (for as long as possible) for the class to resolve them ... "

We saw how passive learning creates motivational ("waiting it out") and crowd control problems. Schoenfeld describes an incident relevant to this problem.

> *"The students work in small groups for perhaps half the class. Then we convene as a whole to discuss those problems ... One day toward the end of the term I had an unavoidable conflict during the first part of class. I asked a colleague to hand out my problem set; the students could work by themselves for a while, and I'd join them when I could. Unfortunately, I was detained, and only managed to get free after class was over. I ran to the room where the class met, arriving fifteen minutes after class should have ended. All the students were still there, still in small groups, arguing over the problems" (pp.12-13).*[3]

Passive learning encourages what we called veneers of accomplishment by learners. Schoenfeld observes that

> *"At their own level the students are mathematicians, engaged in the practice of mathematical sense-making. They do mathematics, with the same sense of engagement and involvement. The difference is that boundaries of understanding that they challenge are the boundaries of their own understanding, rather than those of the mathematical community at large ... "*

This engagement with the real stuff of mathematics, the debate and argument over problems, are antithetical to sounding and testing "right" within the school system, but often without real learning.[4]

3 As the State of Vermont has moved to portfolio assessment, classrooms are looking more and more Schoenfeld's and finding the same motivational effects. Joan Simmons, an eighth-grade English teacher, has found that "As a teacher, you have to be willing to give up control, give up being a talking head. But if you do, after a little confusion, the rewards are fantastic. Discipline problems got out the window and the kids are engaged." (New York **Times**, April 24, 1991, p. A23).

4 Again, schools in the State of Vermont seem to creating environments that produce deep, not superficial learning.

> *"In Mrs. Rainey's eighth-grade algebra class at Shelburne Middle School in Shelburne, Ryan Galt, 13, swiftly explained with lighted overhead projector how he got the solutions to problem. He calculated madly, his pencil flying through the numbers as he talked*
>
> *Suddenly out of the darkened classroom came the kind of sheer admiration usually reserved for a wheeling, over-the-head basketball jam by the Chicago Bulls guard Michael Jordan 'Jeez, that's sweet,' cried Casey Recupero. He had had the same correct answer as Ryan, he explained but was delighted by the other student's elegant methodology.*
>
> *As the class ended, clusters of students compared their approaches to the problem with the passionate ardor that teachers everywhere dream of inspiring. 'I had an interesting way of doing it, but I messed up,' one student said. 'That's because you did this here,' his classmate said, pointing out an error "* (New York Times, April 24, 1991, p. A23).

CHAPTER IV.

Cognitive Apprenticeship Models

These precedents—nineteenth century innovations, analyses of the "spectacular" learning of the young child, actual attempts by cognitive scientists to create different kinds of learning environments, and the serious body of cognitive science research—add up to a solid foundation for designing effective learning environments. Collins, Brown, and Newman (1989) have proposed what they believe to be key elements of these environments, calling the emergent model "cognitive apprenticeship."

The cognitive apprenticeship model modifies traditional apprenticeship to teach symbolically-based and therefore less observable activities, such as reading, writing, and mathematics. *The term "cognitive" should not be read to mean "academic."* The model de facto ignores our usual distinctions between "academic" and "vocational" education, in that its objective is to entrain the novice into communities of expert practice, whether the practice is what the rest of us might call "academic"—for example, mathematics, or "vocational"—for example, interior design.[5] In other words, the model presumes that learning is learning, however the rest of us may choose to label the domain being studied. And in fact, as the American economy and its skill requirements restructure, many "vocational" domains involve substantial amounts of symbolic activity.[6]

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5 The subtitle of the authors' original paper on cognitive apprenticeship is revealing in this respect, "teaching the craft of reading, writing, and mathematics." The subjects might be seen as "academic," but their practice is defined as craft.

6 In the modern economy more and more occupations that previously depended primarily on the skilled hand and the skilled eye now also require facility with symbolic material. For example, in traditional machining, responsibility for part dimensions and tolerances, metal properties, and tool use is literally in the hands of the machinists whose knowledge of part geometry, metallury, ouput requirements, and tool functioning is extensive. Computerized numerical control (CNC) machines radically alter these processes of setup, control, and operation, a decisive transformation being that they replace manual setup and control with setup by symbolic command. Whereas the machinist working on a traditional machine reads an engineer's blueprint and then manually adjusts dials and levers to set up a particular operation, a machinist on the CNC machine reads the blueprint and then creates commands in a programming language to govern the machine's operations (Martin, Scribner, and Beach, 1990).

In the textile industry, textile machines used to be mechanically based. Workers could *visually* observe how they operated, and working around them gave operators a sense of how to repair them. The additional training needed to become a "fixer" was acquired on the job with little or no formal instruction. This situation has now changed. Most machines now have microprocessors and other electronic components. Since important machine components are not visually observable, operating the machines does not provide much of a sense of what it takes to repair and maintain them Now to understand, diagnose, and fix the new machines, technicians have to be able to represent their structures and processes *symbolically* in their heads. To do this they have to be able to follow complicated manuals, diagrams, and updates provided by the manufacturers. Literacy requirements have accordingly shot up

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Collins, Brown, and Newman (1989) argue that the most important difference between formal schooling and apprenticeship is that, in schooling, skills and knowledge are abstracted from their uses in the world; in apprenticeship, they are continually used by skilled practitioners and are instrumental to accomplishing meaningful tasks. In other words, "apprenticeship embeds the learning of skills and knowledge in their social and functional context."

Thus, their focus is on learning-through-guided-experience, but emphasizing cognitive, rather than physical, skills and processes. As the reader saw, traditional apprenticeships teach domains in which the target skills, such as expert tailoring, are visually observable—they are "external" in the sense that they can literally be seen.

Visually observable or "externalized" skills make them available to students and teachers for "observation, comment, refinement, and correction." Externalized skills bear a fairly transparent relationship to concrete products, such as the assembly of pieces into a shirt. This ability to see the relevant skills, procedures, and resulting products helps the student build a conceptual model of the complex target skill—to envision his or her ultimate performance goal. And the relatively transparent relationship, at all stages of production, between process and product facilitates the learner's recognition and diagnosis of errors, upon which the early development of self-correction skills depends.

However, applying apprenticeship methods to skills that are not particularly visually observable—in other words, to largely cognitive skills—means that ways have to be found to "externalize" processes

> *"that are usually carried out internally ... [A]s most subjects are taught and learned in school, teachers cannot make fine adjustments in students' application of skill and knowledge to problems and tasks, because they have no access to the relevant cognitive processes. By the same token, students do not usually have access to the cognitive problem solving processes of instructors as a basis for learning through observation and mimicry" (pp.4-5).*

Defining Characteristics of Cognitive Apprenticeship

Keeping this challenge in mind and analyzing exemplary instructional programs in reading, writing, and mathematics, Collins et al. identified characteristics of ideal learning environments. These are summarized in Table 1. Their model has four building blocks—what Collins et al. call "content," "methods," "sequence," and "sociology." It is these pieces *working together* that define an effective learning situation.

For example, any learning situation has to build the student's "domain knowledge"—his or her conceptual and factual knowledge and procedural capabilities in particular subjects. However, if this knowledge is learned in isolation from realistic problem contexts and expert problem solving practices, it remains inert in situations for which it is appropriate. In other words, *it will not transfer.* It is only through encountering domain knowledge in real problem contexts that most students will learn its boundary conditions and implications for other situations. In other words, the key lies in yoking several of the model's principles together in the learning situation.

Examples of Cognitive Apprenticeship

Any statement of principles is abstract, if not esoteric, and the number involved in cognitive apprenticeship seems daunting. However, we find instances of such apprenticeships, not just in the annals of cognitive scientists, but also in real world high school vocational courses and projects, designed by real world high school teachers.

Table 1.—Characteristics of Ideal Learning Environments

Content

Target knowledge for an ideal learning environment includes domain-specific conceptual, factual, and procedural knowledge and three types of strategic knowledge. Schools usually focus only on the first type of content. However, the last three types are needed to operate effectively in, on, and with domain-particular knowledge.

- **Domain Knowledge:** the conceptual and factual knowledge and procedures associated with a particular subject.
- **"Tricks of the Trade":** called more formally "heuristic strategies", these are problem solving strategies that experts pick up with experience. They do not always work, but when they do, they are quite helpful.
- **Cognitive Management Strategies:** these control the process of carrying out a task and are also known as "executive thinking" skills or "metacognitive" skills. They include goal setting, strategic planning, checking for accurate plan executive, goal-progress monitoring, plan evaluation, and plan revision.
- **Learning Strategies:** these are strategies for learning any of the kinds of content described above. Knowledge about how to learn includes general strategies for exploring a new domain. It also includes strategies for getting more knowledge in an area already somewhat understood and reconfiguring the knowledge already possessed.

Methods

Teaching methods should be designed to give students the chance to observe, engage in, invent or discover expert strategies in context.

- **Modeling:** for students to model expert performance, the learning situation must include an expert's performing a task so that the students can observe and build a conceptual model of the processes that are required to accomplish it.[7]
- **Coaching:** this means observing students as they carry out a task and offering hints, support, feedback, modeling, reminders, and new tasks to bring their performances closer to expert performance.
- **Scaffolding and Fading:** "scaffolding" is like the physical support structure that is put up on buildings. Here it refers to the supports that the teacher provides to help the student carry out the task. Supports can take either the form of suggestions or help or actual physical supports, such as the short skis used to teach downhill skiing. "Fading" is the same idea as weaning a baby: the gradual removal of supports until students are on their own. Fading is critical to autonomous and independent functioning.
- **Articulation:** this includes any method to get students to articulate their knowledge, reasoning, or problem solving processes in a domain. It gets at the "blank slate" problem.
- **Reflection:** this is any technique that lets students compare their own problem solving processes with those of an expert, another student, and, ultimately, an internal cognitive model of expertise. The student presentations in the Shelburne, Vermont, eighth-grade algebra class are such devices.
- **Exploration:** this refers to any device that pushes students into a mode of problem solving on their own. Forcing them to explore is critical, if they are to learn how to frame questions or problems that are interesting and that they can solve. This part of the model provides the opportunities for experiential feedback so key to learning.

7 In cognitive domains, this requires the externalization of usually internal cognitive processes and activities. For example, an expert's exercise of self-management skills is normally a silent and unobservable activity. In cognitive apprenticeship situations the expert (teacher) might model the reading process by reading aloud in one voice and verbalizing his/her thought processes in another.

Table 1.—Characteristics of Ideal Learning Environments (continued)

Sequencing

Learning should be "staged" so that the learner builds the multiple skills required in expert performance and discovers the conditions to which they generalize.

- **Increasing Complexity:** this refers to the construction of a sequence of tasks and task environments so that more and more of the skills and concepts necessary for expert performance are required.
- **Increasing Diversity:** this refers to the construction of a sequence of tasks in which a wider and wider variety of strategies or skills are required so that students learn to distinguish the conditions under which they do (and do not) apply. (This principle is key to students' seeing transfer possibilities and their limits.)
- **Global Before Local Skills:** this simply means staging the learning so that students first develop a "feel" for, sense of, a conceptual map of, the overall terrain before attending to its details. (In tailoring apprentices learn to put together a garment from precut pieces before learning to cut out the pieces themselves.) Having a mental image of the overall activity helps the student make sense of the sub-activity that he or she is carrying out. It also acts as a guide for the learner's performance.

Sociology

The learning environment should reproduce the technological, social, time, and motivational characteristics of the real world situations in which what is being learned will be used.

- **Situated (Contextualized) Learning:** this refers to students' carrying out tasks and solving problems in a way that reflects the nature of such tasks in the world. For example, reading and writing instruction might be situated in the context of an electronic message system that students use to send each other questions and advice.
- **Community of Expert Practice:** this refers to the creation of a learning environment where participants actively communicate about and engage in the skills evidenced by experts. In other words, the learning situation needs to include experts and learners; experts performing tasks; and learners being drawn into the community of expert practice by watching experts, working with experts to solve problems and carry out tasks, and coming to assume autonomous control over problems and tasks.
- **Intrinsically Motivated Learning:** this refers to the incentives that govern the learning situation. Intrinsic motivation arises when students are engaged with interesting or at least coherent goals, rather than for some extrinsic reason, such as pleasing the teacher.
- **Co-operative Learning:** this refers to having students work together to solve problems and carry out tasks. Learning through cooperative problem solving is both a powerful intrinsic motivator and a way to extend learning resources. For example, in contemporary computer clubs nonexperts were able to use each other as "scaffolding" for increasing their command of computers. They pooled their fragments of knowledge about computers to bootstrap themselves toward expertise (Levin, 1982).
- **Competitive Learning:** this refers to giving students the same task to carry out and then comparing their performances to focus their attention on strengths and weaknesses. Learning in today's classrooms is competitively and usually destructively structured. For competition to be constructive, comparisons should be made, not on the products of student problem solving, but on the processes that generate the products. The learning objectives for students should be defined, not as making no errors, but as learning to spot errors and using an understanding of them to improve. Combining co-operative and competitive learning can mitigate the destructive aspects of competition: for example, students might work together in teams to compete with other teams, thus letting them use team members as scaffolding and comparisons of team performances to focus attention on better and less-good ways to carry out a task.

Building and racing a solar-powered car

At the National Council on Vocational Education's "Time for Action" Forum, students from Conval High School in Peterborough, New Hampshire, and their teacher, William Bigelow, displayed and discussed the solar-powered car that the students had built as an applied science project (National Council on Vocational Education, 1990). The project evidences all four blocks of the cognitive apprenticeship model; we point out particular principles when they are especially obvious.

The project extended over nine months, an unusually long time frame for a school, but a realistic one for real world tasks [*sociology of the learning situation*]. It culminated in the team's competition in a 234-mile, five-day race from Montpelier, Vermont, to Boston [*combined co-operative and competitive learning*].

The project required the students to acquire and use a wide variety of skills spanning many academic and practical disciplines, including physics and mathematics, basic solar engineering, hydraulics, electronics, drafting, model fabrication, metal working, and welding [*domain knowledge, control and learning strategies, increasing complexity*]. Ten models were built and tested before the students finally decided on a production design [*control strategies, reflection, increasing diversity, co-operative learning, competitive learning*—where the competition is between group-generated alternative designs].

The students quickly learned the necessity for other skills as well. They had to acquire the business skills necessary to manage some grant funds. They also had to learn the English, journalism, and graphics skills needed for a public relations effort about the project [*domain knowledge*]. Perhaps most surprising to the students, they had to acquire the leadership, management, and interpersonal relations skills necessary to construct a rational division of labor to keep the project moving forward [*domain knowledge*]. Among the more significant outcomes of the management process was a negotiated decision to build the car for racing safety at the sacrifice of speed [*articulation, reflection, exploration, increasing complexity, co-operative learning*].

Mr. Bigelow, the instructor, had four educational goals: (1) the project should control curriculum in a way that enabled students to see worthwhile connections between their work and real environmental and economic problems [*situated learning*]; (2) the students would become managers of their own learning—in other words, they would learn what they needed to know to accomplish specific goals through team decision-making [*fading, exploration, co-operative learning*]; (3) the project would integrate study across the curriculum—for example, the project's success depended as much on a solid PR effort involving journalism skills as on understanding the physics of photovoltaics [*increasing complexity*]; and (4) the students would learn the necessity for building bridges to critical local resources to acquire the technical support and financial assistance required.

Designing the six-room interior of an historical Victorian house

Stasz et al. (1990) describe a high school interior design class where students had six weeks to complete a contemporary interior design for an historical Victorian house. They had to research the original house and the design tradition, draw the house, draft the floor plan, select furnishings and coordinate colors, and prepare boards to display the proposed design. Most of the students worked in teams of four to six people, but some worked individually.

To help students learn from errors, the teacher frequently provided active coaching and support. However, in general, she backed away from active coaching. She tried to structure the project assignment so that it naturally produced opportunities for students to learn skills such as "monitoring as you go" [*cognitive management strategies*].

She worked to foster what Collins et al. call *exploration.* Although some aspects of the interior design project were constrained, she deliberately under-constrained the task to encourage students to create their own problems and solutions. She pushed students to the boldness and risk-taking associated with exploration.

> *"Bob shows Ms. Adams a wallpaper sample in beige. Ms. Adams looks at it and asks Bob if he can't 'come up with something less safe.' Bob, looking puzzled, asks what is wrong with beige. Ms. Adams turns the question around, but Bob cannot respond. She explains that beige is not a design challenge: 'There is nothing to do with it. You can't make a mistake with it.' She then told the research team: 'If I had spoon-fed the kids, it would have defeated the whole purpose of the project; they would have never shifted gears. They were frustrated when they did not get the answer, but they learned that it's okay for them to have an opinion as long as it's backed by a rationale ... Liking something is not enough'" (p.26).*

Redesigning the American Constitution

Salomon (1990) describes a project for studying the American Constitution. Recognizing that studying constitutions is not very exciting for eighth graders, the designers first thought about structuring the project so that the students could create a computer database that they could use to sort information, reconstruct it into newly invented categories, and so forth. However, they immediately asked themselves: Why would students want to do this?

> *"One rarely classifies novel information and cross-tabulates it without having a motive, a reason, a purpose for doing so. And how does one classify legal clauses, according to what criteria, in the absence of a clear purpose?" (p.8).*

Salomon and his colleagues were struggling with the issue of *meaning* for the students [the problem addressed by authentic *situated learning*].

They created a purpose. The students took the positions of different stakeholders—the federalists, the loyalists, representatives from the different colonies (New York, Pennsylvania, Virginia, etc.), plantation owners. Working in teams of three *[cooperative learning]*, the students treated the Constitution as a *draft*, the study teams proposing changes in it according to their stakeholder perspectives. This gave them reason and framework for dealing with the Constitution in database form, inviting them to reclassify its legal clauses, compare them, and draw out their implications for their political positions. They then formulated proposed changes in the Constitution, to be introduced in subsequent inter-team debate.

In other words, the Constitution is not treated as The Word, but as a document that was originally built out of dynamic political forces and that students can rebuild in the same spirit *[exploration]*.

The project culminated in a Constitutional Convention, where the teams, as delegations and under the guidance of George Washington (the teacher), debated the changes that they wanted adopted. Three students became clerks of the Convention to count votes and announce decisions, and other students served as an audience. Creating a position to take to the Convention generated opportunities for *articulation*—of positions, knowledge, reasoning, and problem solving—and for *reflection*—letting each student compare his/her own problem solving processes with those of other students in the team. The Constitutional Convention created more opportunities for articulation, reflection, and, because it had important elements of *competition* and public comparison for focusing the teams' attention on the strengths and weaknesses of their performances.

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CHAPTER V.

How Do Cognitive Apprenticeship Ideas Fit Other Policy Proposals and Programs?

Cognitive apprenticeship addresses what is learned—recall the Content part of Table 1. However, its primary implications are for how teaching and learning occur: for the role of the teacher; for the design of the social, technological, and motivational environment for learning; and for the "staging" of learning challenges.

How do these ideas fit into policy discussions about different models of integrating academic and vocational education, work-based apprenticeship (work-based learning), technical preparation ("tech prep") and 2+2 programs, and cooperative education?

Relationship to Models for Integrating Academic and Vocational Education

Since support for integrating academic and vocational education has so many strands and schools differ so much in structure, students, and objectives, integration efforts differ significantly in form and ambition (Grubb and Plihal, 1990). Grubb and Plihal identify eight models of integration from their observations of programs that defined themselves as integrating academic and vocational education.

These eight were:

(1) incorporating academic competencies into vocational courses;

(2) combining academic and vocational teachers to incorporate academic competencies into vocational courses, the difference between models 1 and 2 being collaboration between academic and vocational faculties;

(3) making the academic curriculum more vocationally relevant, a model that ranges wildly in purpose from making academic courses more relevant to vocational students to remedial education or electives unconnected to vocational education;

(4) modifying both academic and vocational education and curricular alignment, making academic courses more occupationally-relevant and vocational courses more academic and then linking the two either horizontally or vertically;

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(5) setting up academies within schools. These combine academic and vocational faculty in a subject, such as electronics, that gives focus to the Academy. These teachers stay with a group of students for all courses across several years. The possibilities for the horizontal and vertical alignment of courses are greatly increased.

(6) replacing conventional academic and vocational departments with departments organized around occupational clusters;

(7) focusing the whole school, not just an academy-within-a-school or occupationally-organized departments within a school, on a single occupation;

(8) maintaining conventional academic and vocational departments, but with students and teachers organized around "career paths" or occupational clusters in a matrix structure. Both academic and vocational faculty interact to frame the school's courses, and the career path structure forces students to think harder about their occupational futures.

These models differ primarily in their organizational arrangements and the depth and breadth of the integration of academic and vocational education. The curricular ("what") and pedagogic ("how") principles of cognitive apprenticeship are not only consistent with integration ideas. *We propose that they in fact rigorously define what a vocationally and academically integrated learning environment should look like.*

The policy motivation for integrating academic and vocational education is to use the best of vocational education pedagogy (the "how" of teaching) for learning academic material and for infusing vocational curricula with much more rigorous academic content. The best of vocational education reflects several of the pedagogic principles of cognitive apprenticeship; the best of academic education, its content principles. *Thus, cognitive apprenticeship can function as the grounded curricular and pedagogic model for integrating academic and vocational education*—as the model for what to teach and for how to teach it. For example, good vocational education is more apt to use some of the methods (such as modeling, coaching, or scaffolding and fading) and sociology (such as contextualized and co-operative learning) of cognitive apprenticeship than good academic education. However, even when vocational education picks up pedagogic elements of cognitive apprenticeship, it is generally weaker on the content side—in academic knowledge and the higher order cognitive skills—the heuristic strategies, cognitive management strategies, and learning strategies. The principles of cognitive apprenticeship *systematically* preserve and integrate the best of academic and vocational education into a single model that can be used to teach mathematics or interior design, the main difference between the two residing in one element: domain knowledge.

We now see elements of cognitive apprenticeship in integrated programs, but these elements are often implicit, accidental, and idiosyncratic. In other words, they are rarely the result of explicit design, and they are not routinely found.

Work-Based Apprenticeship (Work-Based Learning)

At least two factors have motivated an explosion of interest in work-based apprenticeships. One is the lack of a national system that moves young people from school into the workplace—or even smoothly between occupational preparation programs. The other is the recognition that most school-based programs—even many vocational ones—are divorced from the needs of the workplace. The disconnect includes both the knowledge and skills needed at work and the ways in which knowledge and skills are used in work contexts.

"Workplace apprenticeship" presumes: (1) an apprenticeship learning situation, and (2) the workplace as the locus of that situation. *These represent two separable assumptions*; one does not logically entail the other.

One of two reasons for conceiving of these apprenticeships as work-based seems to be that, if your concern is to move youth into the workplace, *the best way to do this is to put them there*. The other seems to be that if school-based programs are bad learning places for work, workplaces must be good places—which may turn out to be true empirically, but is bad logic. In fact, evidence on informal on-the-job training and on employers' training investment patterns suggest that workplaces are not good learning places for the young and the less educated.[8] We may face a Hobson's choice between two worlds (schools and work), both currently badly designed for powerful learning.

Relative to work-based apprenticeship, cognitive apprenticeship is interesting in fou. ·'ays.

- **First:** the cognitive apprenticeship model is a grounded model for effective learning. In that sense it is as relevant to work-based apprenticeships as to school-based programs.

- ›econ‹ Collins et al. (1989) discuss two differences between cognitive and tra itional apprenticeships that may be relevant to a work-based versu‹ school-based cognitive apprenticeship. We think these differences are potentially relevant to any work-based learning, whether called "work-based learning," "work-based apprenticeship," or "co-operative education." Whether these potential differences become real depends on whether in work-based apprenticeships the work process is deliberately altered to facilitate learning.

In traditional work-based apprenticeships, the problems and tasks given to learners arise not from pedagogical, but from workplace, concerns.

> *"Cognitive apprenticeship selects tasks and problems that illustrate the power of certain techniques, to give students practice in applying these methods in diverse settings, and to increase the complexity of tasks slowly so that component skills and models can be integrated. Tasks are sequenced to reflect the changing demands of learning. Letting job demands select the tasks for students to practice is one of the great inefficiencies of traditional apprenticeship" (Collins et al., 1989).*

At the same time, they point out that the work-centered ("economic bias") nature of traditional apprenticeships means that

> *" ... apprentices are encouraged to quickly learn skills that are useful and therefore meaningful within the social context of the workplace. Moreover, apprentices have natural opportunities to realize the value, in concrete economic terms, of their developing skill: well-executed tasks result in saleable products" (Collins et al., 1989).*

The bottom line is that unless work-based apprenticeships are deliberately designed for doing-based *learning*, a work-based course of study will probably have potentially serious holes and inefficiencies. At the same time, the press of the workplace—"keeping the line going"—and the motivating feedback of being engaged in actual economic activity probably mean that the apprentice learns better and faster whatever the workplace demands he or she learn.

8 Analyses of employers' training investments show that employers focus their formal training on the better educated and on the not-so-young (Tan, 1989). Observations of informal on-the-job training of the less educated suggest that this training is catch-as-catch-can. Its quality depends heavily on who happens to be around to train. In work groups with high turnover. almost-novices are training novices, a situation that violates all models of good apprenticeship training. Even experienced members of a group can only pass on their understanding of the job and the corpporate context in which this is embedded This understanding is rarely monitored and can vary widely (Scribner and Sachs, 1990)

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- **Third:** the principles of cognitive apprenticeship were derived from *school-based* programs that had consciously tried to implement the implications of cognitive science for learning. In other words, the design has been implemented in schools, indicating that there is nothing *logically* incompatible between the design and schools.

- **Fourth:** cognitive apprenticeship is designed for or is compatible with learning the generic skill requirements of the modern workplace (e.g., Berryman, 1990; SCANS, 1991; Stasz et al., 1990). We do not have to situate the design in the workplace to develop generic workplace skills.

What all this says is that a cognitive apprenticeship strategy may well be able to deliver powerful learning relevant to the workplace in a school-based environment. Given the sobering obstacles that are emerging as we gain experience with work-based apprenticeships, the option of school-based cognitive apprenticeships must be considered.

Technical Preparation ("Tech Prep") and 2+2 Programs

In federal law technical preparation ("tech prep") denotes a four-year curriculum, starting in the last two years of high school and leading to an associate degree in a technical field of work—hence the term "2+2." The courses are expected to integrate academic and vocational content and to be vertically integrated (co-ordinated) across the four years and across high schools and community colleges (Stern, 1990).

These programs are like some of the academic vocational integration models, except that they are expected to span both high schools and community colleges. The relationships between these programs and cognitive apprenticeship ideas are the same as those between cognitive apprenticeship and the academic/vocational integration models discussed earlier.

Cooperative Education

Cooperative education (co-op) deliberately alters the work process to facilitate learning and is more school-based than work-based apprenticeship. The student's classroom instructor arranges job placements, writes a training plan detailing what each student is expected to learn on the job, and visits students' job sites to monitor the training. The students' job supervisors evaluate their performances in terms of training objectives (Stern, 1990).

In theory, cognitive apprenticeship principles could be built into co-op programs. However, essentially co-op has to take the workplace as it finds it, fitting training plans around the uneven training skills of supervisors and supervisors' uneven (and often limited) authority to alter the work process to support learning.

In the Final Analysis: How Effective Is Cognitive Apprenticeship?

We do not yet know, especially if the question is whether cognitive apprenticeship is effective in routine, as opposed to hot house, intense, concentrated learning situations. However, the ideas do not come out of nowhere; in fact, they are unusually well grounded.

Cognitive apprenticeship strategies build on traditional apprenticeship, a tested, cross-cultural strategy for effectively acquiring visually observable skills. They build on and incorporate the ideas and findings of a community of serious thinkers and researchers, from John Dewey to today's cognitive scientists.

However, learning situations that reflect cognitive apprenticeship principles are not abundant. Extending them requires dealing with institutional, curricular, pedagogic, evaluation, and professional training issues. The model itself will change as we gain experience with it in the bruising real world of teaching and learning.

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The Council is mandated by Congress to meet four times a year. The four meetings in fiscal year 1990 were held:

- *December 2, 1989 in Orlando, Florida*
- *February 4 & 5, 1990 in New York City, New York*
- *May 20 & 21, 1990 in Washington, D.C.*
- *September 16 & 17, 1990 in Washington, D.C.*

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