ACQUIRING INTELLECTUAL SKILLS

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INTRODUCTION

This review is concerned with how intellectual skills are acquired, and covers the literature from 1988 to 1993. As we use the terms, intellectual refers to skills important to human mental activity and acquisition refers to how such
skills are learned. Although the review follows most closely from Glaser & Bassok's (1989) review of instructional psychology, the present chapter's title acknowledges that intellectual skill acquisition takes place in non-classroom as well as classroom situations. This review addresses four topics: domain-related intellectual skill acquisition, general intellectual skills, social contexts, and some significant issues.

**DOMAIN-RELATED INTELLECTUAL SKILL ACQUISITION**

Three domains are considered here: mathematics and physics, in which most of the research has occurred, and history, which has received increasing attention. The research generally has been concerned with how a priori conceptual knowledge influences learning and reasoning.

**Mathematics**

In recent years there has been a relatively large amount of research on mathematics learning concerned with 1. students' prior knowledge, including preschool intuitions and out-of-school learning, 2. the interaction of language and symbolic mathematical expressions, 3. metacognitive skills; and 4. socially interactive processes.

**INTUITIVE MATHEMATICS** What constitutes intuitive knowledge of preschool children and how such knowledge impacts mathematics learning have been questions of interest. Resnick (1989) noted that young children's knowledge of size differences, of concepts such as big and little, of increases or decreases in amount, and of part-whole relationships are reasonably well established before school years, as sometimes are counting skill and calculation strategies. Resnick (1989) therefore suggests that formal instruction, generally emphasizing mathematical routines, may be more beneficial if built upon intuitions, as exemplified by Resnick & Singer's (1993) study of ratio reasoning. Similarly, Levine et al (1992) reported results consistent with the idea that young children's ideas of adding and subtracting emerge from combining and separating objects in the real world.

**MATHEMATICS LEARNING** Studying the acquisition of addition, subtraction, and multiplication skills and working within a competition-of-response model, Siegler has examined strategy learning in subtraction (Siegler & Jenkins 1989), strategy choice as related to domain-specific and domain-general knowledge (Siegler 1989), and intraindividual variability in strategy selection (Siegler & Jenkins 1989), the latter also studied by Ohlsson & Bee (1991).
The study of solving algebra word problems has indicated that a deficit in language processing is more critical to problem solving than is a deficit in the use of mathematical algorithms (Cummins et al. 1988). In addition, better learners more accurately map the understanding of the problem statement to the needed equations (Nathan et al. 1992), and poorer students show poor understanding of the mathematical symbol system and the described situation (Greeno 1989, Hall et al. 1989). Understanding of word problems is also related to the discrimination of relevant and irrelevant problem information (Littlefield & Rieser 1993) and to the ability to indicate the necessary and sufficient conditions required to solve a problem (Low & Over 1989).

Sweller (1988) has argued that students can solve problems without improving in their problem solving skill. Strategy-based operations, such as means-ends analysis, take up working memory capacity, thereby providing little opportunity for schema acquisition, that is, learning to categorize problems and to apply particular rules (e.g. Ayres & Sweller 1990, Zhu & Simon 1987).

Street Mathematics and Culture Cross-cultural research, comparing American, Japanese, and Taiwanese first and fifth graders, has indicated that students in the United States spend less time in school and less time on academic tasks than do students in Japan or Taiwan (Stevenson et al. 1987). Fernandez et al. (1992) also demonstrated that Japanese students enter class with better mathematical representations than do American students. In home life, Asian families take education more seriously than do American families, with Japanese and Taiwanese students spending more time doing homework and academic-related activities (Stevenson & Stigler 1992).

Reviewing a series of Brazilian studies, Nunes et al. (1993) concluded that mathematics learning has two components: 1. the social component of how mathematics is practiced in the real world, and 2. the logical or symbolic component of how mathematics is acquired in school. Coconut vendors aged 9–15 correctly performed price computations in the market place but did not perform as well when the problems were stated formally. Saxe (1988, 1991) also found that vendor and nonvendor groups matched for age and schooling represented numerical quantities in similar ways but vendors developed better computational strategies. Schliemann & Acioly (1989) found that bookies aged 23–65, varying in schooling from 0 to 11 years, were accurate when selling mathematically complex lotteries, but more schooling yielded better justification of the calculations and better performance on unusual problems. Nunes et al. (1993) also reported that uneducated fishermen, based on their work demands, developed a general schema for calculating quantity and price in proportionality problems. Nunes et al suggest that “realistic mathematical
problems" (i.e. those that capitalize on the real world experience of students) should be used in school.

TEACHING OF MATHEMATICS The Cognition and Technology Group at Vanderbilt (CTGV) has combined a theoretical position with technology in its research on mathematics instruction. The CTGV program involves presenting a video-based narrative adventure of a fictitious character, after which a realistic and relatively complex problem is asked that is based on the video contents. Students, usually working as a class or in small groups, subsequently generate a detailed solution plan. The instructional program assumes that student learning is anchored in complex, realistic situational events in which students can engage (CTGV 1990). The program has yielded results superior to typical instruction in specific calculations and general problem orientation (CTGV 1993). In addition, assessment measures have yielded positive outcomes (CTGV 1992).

Schoenfeld (1987, 1988, 1991) has stressed that children need to use mathematics as a tool for recognizing and solving problems, instead of trying to find the answer as quickly as possible. Schoenfeld (1988) has noted that traditional instruction does not accomplish this goal even when students learn the course contents. Schoenfeld has also discussed the importance of metacognition and social factors to mathematics instruction, that is, how knowledge of one's own thought processes and the use of self-monitoring procedures as well as participation in small groups facilitate performance (Schoenfeld 1987).

Lampert (1990) has emphasized collaborative argumentation in a classroom as a means of developing mathematical proofs. Lampert suggests that students need to see mathematics as both a deductive and an inductive process. To do this, students must engage in mathematical arguments in which they develop and defend strategies, state hypotheses, and question and defend assumptions. Movement toward this goal was demonstrated in a fifth grade class that emphasized these procedures. Fennema et al (1993) have demonstrated that when a first grade teacher used their cognitive approach, termed Cognitively Guided Instruction, the students performed above a national standard level.

Physics

Recent research in physics has largely been a continuation and refinement of work of the 1980s, which emphasized physical concepts as they are held by naive subjects, especially in relation to misconceptions (e.g. McCloskey 1983, McCloskey & Kargon 1987). Current research generally constitutes an extension of this work.
PERSISTENCE OF NAIVE PERCEPTIONS  Studies continue to indicate that although studying physics improves performance on physics problems, naive conceptions of physics are maintained with complex problems (Pozo & Carretero 1992, Villani & Pacca 1990), with more familiar problems (Kaiser et al 1986), and as a function of problem type (Donley & Ashcraft 1992). However, by providing appropriate experiences, Levin et al (1990) were able to produce conceptual change that reduced the maintenance of naive conceptions.

PIECEMEAL KNOWLEDGE AND COHERENT KNOWLEDGE  A controversial issue has been whether naive performance reflects an incorrect but coherent theory of physical causation versus the use of bits of knowledge that are applied to particular situations (see Ranney 1994). diSessa (1993) has argued that naive individuals do not have a coherent theory but have basic phenomenological primitives, pieces of knowledge related to physical activity. The primitives are activated by stimuli and provide a "sense of mechanism" regarding the physical world. Learning then takes place as the primitives, serving as part of a developing structure, increasingly serve as cues and heuristics to access acquired principles. Supporting the position with student protocols, diSessa (1993) noted that traditional physics instruction emphasizes concepts and problem solving and neglects the more naive piecemeal knowledge structures upon which principles are built. McCloskey & Kargon (1987), on the other hand, argue that misconceptions stem from systematic beliefs or intuitive theories.

UNDERSTANDING PHYSICS CONCEPTS  Better learners not only have a more developed understanding of the specific physics concepts under study but they also have more usable knowledge that supports understanding of the meaning and application of the concepts. Reif & Allen (1992) supported this conclusion with respect to the concept of acceleration and Robertson (1990) did so for Newton's second law. Also, Dufresne et al (1992) found that requiring novices to perform a qualitative analysis of the concepts of physics problems before solving them improved novice understanding. Difficulties in understanding the concept of matter have been studied in students aged 13–16, with matter viewed at one extreme as a homogeneous substance and at the other as a particle system (Renstrom et al 1990).

ACQUIRING PHYSICS CONCEPTS: SELF-EXPLANATIONS  Chi et al (1989) found that compared to poor learners, good learners in solving physics problems explain each step to themselves; refine, elaborate, and evaluate conditions needed to take a step in the solution process; consider sequences of actions; explain the meaning of quantitative expressions; monitor their understanding; and refer back to examples with a specific goal in mind rather than trying to find the solution. Also, good solvers are likely to construct inference rules
relating concepts and quantitative expressions (Chi & VanLehn 1991). Using

text describing the human circulatory system and prompting subjects for self-

explanation, Chi et al (1994) also found that high explainers learned more

and had better mental models when prompted to explain than did low

explainers.

History

Researchers studying the acquisition of historical concepts are faced not only

with the question of what skills need to be acquired in history, but also with

controversial issues concerning the goals of historical inquiry and instruction.

Seixas (1993a), for example, notes that the teaching of history often is used to

embrace student identity, but in the United States there are politically volatile

arguments about what identity to embrace. In American history, the traditional

approach emphasizes the Revolutionary War, Lincoln and the Civil War, etc,

while more recent social history emphasizes the historical origins of different

ethnic cultures, thereby facilitating student identity with appropriate minority

groups. Despite these problematic issues, research on learning in history has

focused on concept acquisition, causal reasoning, and learning from text.

ACQUIRING HISTORICAL-POLITICAL CONCEPTS Although limited in number,

studies involving the acquisition of historical-political concepts have shown that

the ability to acquire such concepts is a function of age. Working within a

Piagetian framework, Berti (1994) studied how children develop political con­

cepts (e.g. state or government). She found that such concepts were incomplete

for third graders, had emerged by fifth grade, and became more developed by

eighth grade. Delval (1994) found a similar pattern of concept learning across

cultures. von Borries (1994) showed that student understanding of historical

concepts is not based solely on cognitive considerations. For example, students

sometimes respond to questions about the Crusades in moral as well as emo­

tional ways, and students’ moral standards can play a role in such reasoning.

Carretero et al (1991a) showed that students are relatively poor estimators of

the sequence of historical events. Seixas (1993c) found that students of a

particular cultural background regard events of that culture as historically

significant, based in part on knowledge they have acquired from their families.

CAUSATION AND EXPLANATION Consider the quote attributed to Pascal, “If

Cleopatra’s nose would have been one-quarter inch longer (thereby making her

less attractive), would the course of Western civilization have been different?”

Scientific reasoning tends to focus on isolating single causes and their possible

interactions, but history must deal with the issue of multiple causation, and with

causation over time. There is also the question of the extent to which causes are

based on particular theoretical explanations of history (Leinhardt et al 1994b).
Furthermore, causal agents in history can refer to individuals, groups, institutions, or to a set of particular conditions (e.g. economic and class issues in Marxist theory). From a learning perspective, however, research has not been concerned with the meta-issues of causation and explanation per se, but rather with how individuals perceive historical causation.

Students regard the actions of individuals as more important than the influence of societal and institutional structures, which are often emphasized by historians (Halldén 1986, Shemilt 1987). Halldén (1986) concluded that the failure of students to understand the nature of history as a subject matter is the primary problem of history learning. Halldén (1993) also showed that although in the classroom Swedish secondary students learned institutional explanations for Sweden’s industrial revolution and establishment of democracy, they nevertheless had an alternative framework, attributing these changes to the suffering of and demands made by the people. Similarly, Carretero et al (1994) found that in rating six causes of why Columbus sailed, sixth and eighth graders rated personal motives as the most important while tenth graders, psychology students, and history students rated economic conditions first. Personal motives were rated second by the tenth graders and psychology students, and fifth by the history students. Voss et al (1994), however, found that students considered both structural and personal factors when writing essays about why the Soviet Union collapsed (e.g. structural factors produced the need for personal action). Students also rated immediate causes as more important than those remote in time. In another study, Hindu students of India tended to emphasize the context as more important than the specific agents (Miller 1986), thereby suggesting that what historical factors are emphasized as causal may be related to culture.

DOCUMENTS Examining written documents and pictorial representations of the 1775 Battle of Lexington, Wineburg (1991a,b) found that expert ratings of document reliability were inversely related to novice ratings. Historians also used three heuristics more frequently than did novices: 1. corroboration—comparing sources for consistency, 2. sourcing—looking at the origin of a source before examining it, and 3. contextualization—determining when and where the event in the document took place. Wineburg (1991a) also noted that historians, but not novices, construct a subtext (i.e. they provide historical meaning to documents, considering especially when and why a text was likely written, who wrote it, and the writer’s possible motives). Perfetti et al (1994) have found that the use of documents as an instructional tool facilitates student learning.

THE TEACHING OF HISTORY A question considered in the field of history as well as other domains is the extent to which students in the domain should be
taught the skills of the domain professional, as opposed to being taught the products of the domain-related research. Seixas (1993b) has noted four characteristics that differentiate the scholarly community from the classroom community: the role of authority, exclusiveness (who is accepted in the community as a member), education, and training. However, Seixas also suggested that both communities need to emphasize inquiry. Holt (1990) has suggested that inquiry may be facilitated by having students generate historical reports using historiographic methods, and Hahn (1994) has recommended the use of historical conflict to facilitate hypothesis testing and development of skills involving evaluation of evidence.

Beck et al (1989) found that the contents of history texts assumed knowledge of concepts that students did not have, that the contents lacked coherence, and that the text goals were not clearly stated. Correcting these deficits, Beck et al (1991) produced texts that yielded improvement in student learning. At a more general level, much text processing research has used the narrative genre, and such research may be applicable to learning from narrative historical accounts. The question of the extent to which history should be regarded as narrative is debatable. Mink (1987), for example, regards narrative as a cognitive instrument, while other writers consider historical writing as narrative as well as expository (cf Topolski 1990).

Leinhardt et al (1994a) studied the role of teacher explanation in history instruction and found that quality teaching in history varies. In one case, instruction involved the reinstatement of basic historical concepts in different historical contexts, whereas in another case teaching involved the study of historical concepts over time. Leinhardt (1994) also has provided an overview of issues of history instruction.

GENERAL INTELLECTUAL SKILLS

Scientific Reasoning Skills

In recent years a substantial amount of research has been conducted on scientific reasoning. The primary focus has been on the interaction between hypotheses and evidence, and the related issue of how evidence produces conceptual change.

REASONING BY SCIENTISTS Dunbar (1994) studied the reasoning of scientists in four biological laboratories. He found that cognitive restructuring occurred when data inconsistent with a hypothesis were obtained, and that project laboratory meetings were especially important when members of a laboratory challenged a presenter’s hypotheses and data interpretation (see also Amigues 1988). Conceptual change also occurred via the use of “local” analo-
gies, but such changes decreased with the distance of analogy from the basic issue. Moreover, "far" analogies, such as those crossing disciplines, did not occur.

Scientists' notebooks have been used to examine the reasoning of scientists. After studying Michael Faraday's notebooks, Tweney (e.g., 1985, 1991) was able to show how Faraday tested hypotheses and integrated different principles and observations in making his discovery of electromagnetic induction. More recently, Ippolito & Tweney (1994) considered Faraday's work on visual deceptions, pointing out how Faraday, as other scientists, started from the senses of the real world and constructed a symbolic reality that was in a sense more real than the "real" world of the senses.

The discovery process of scientific thinking has also been modeled from the contents of diaries, recollections, and other sources. Kulkarni & Simon (1988), in modeling Krebs's synthesis of urea, concluded that the heuristics generally used by scientists were important, as were domain knowledge and idiosyncratic factors such as the learning of new techniques. Similarly, Qin & Simon (1990) demonstrated that Kepler's third law could be "discovered" by college students if they used many of the same heuristics as Kepler.

**SCIENTIFIC THINKING BY CHILDREN AND OTHER NAIVE SUBJECTS**

Research on scientific reasoning in naive subjects has focused on the extent to which naive subjects think like scientists (Nisbett & Ross 1980), and on whether cognitive restructuring is found in response to contrary evidence. In addition, analogy has been studied as a vehicle to facilitate scientific thinking.

Kuhn (1989) has argued that the core relation in scientific thinking is differentiating theory and evidence and correctly evaluating evidence in relation to theory. She has found that children have considerable difficulty in separating theory and evidence when performing covariation tasks (Kuhn 1989, Kuhn et al. 1988). However, Richardson (1992), Sodian et al. (1991), and Ruffman et al. (1993) have found that children as young as 6 or 7 are able to show an appropriate hypothesis-evidence relationship, given an appropriate context. Karmiloff-Smith (1988) has argued that children are theorists, demonstrating that children aged 4 and 5 provide some theoretical ideas and that children aged 8 and 9 develop more extensive theoretical representations of the problem.

In other work on the hypothesis-evidence relation, Klahr & Dunbar (1988) asked subjects about an unknown control function of a robot tank and found that adult subjects used two problem spaces, a hypothesis space and an experimental space. Individuals tended to fall into two categories: the theorists, who searched for hypotheses, and the experimentalists, who attempted to draw conclusions from prior experimental results. Theorists solved the problem in less time and tested hypotheses more specifically, running about one-half the
number of experiments as experimentalists. Klahr & Dunbar also found that confirmed hypotheses were retained about 75% of the time while disconfirmed hypotheses were changed about 45% of the time. Confirmed hypotheses may not have been maintained more frequently because confirmation is often ambiguous (Klayman & Ha 1987). Disconfirmed hypotheses may not have been changed more often because of bias or because subjects could not think of other hypotheses (Klahr & Dunbar 1988).

The question of whether children restructure their concepts in relation to experience has been addressed by Vosniadou & Brewer (1992), who asked first, third, and fifth grade children about the shape of the earth. Although responses were not accurate, 82% of the inconsistencies were explained by five student mental models of the earth; namely, a rectangle, a disc, a dual earth, a hollow sphere, and a flattened sphere. The authors argued that the concepts were based on experiential preconceptions, and that children eventually accept earth as a sphere as a result of changes in their presuppositions that occur via cultural exposure. Brewer & Samarapungavan (1991) have argued further that children, in constructing their models, use thought processes similar to those of scientists, with performance differences attributable to the scientists' greater amount of institutionalized knowledge. In addition, Samarapungavan (1992) has shown that children are able to choose among competing scientific theories if the theories are described in a simple way.

Chinn & Brewer (1993) delineated seven types of responses to anomalous data, one of which was changing the theory. The authors found that the likelihood of theory change is influenced by factors such as the type of anomalous data and the characteristics of an alternative theory, while resistance to theory change is the result of factors such as entrenched beliefs, epistemological considerations, and lack of background knowledge. However, such factors were found to facilitate change on occasion. In an instructional context, Burbules & Linn (1988) presented data contradictory to that previously given and found that the new data produced conceptual change. In sum, the likelihood of cognitive restructuring in relation to specific evidential input apparently varies as a function of a number of factors, including certainty of beliefs and possibility of alternative hypotheses, and, noting Dunbar's results with scientific training, exposure to critical analysis.

Analogical reasoning has been regarded as an important aspect of scientific reasoning, and research on the topic has focused on how an individual maps from a base domain to a target domain. Gentner (1988) has proposed a structure mapping model in which the mapping of the base domain to the target domain involves not the predicate per se but the system of relations (Clement & Gentner 1991). Brown & Clement (1989) have described the difficulties in using analogy to overcome misconceptions. In analyzing analogy usage of children, Goswami
(1991) has concluded that analogical skill competence is followed by metacognitive skill development.

LEARNING SCIENTIFIC THINKING SKILLS  Schauble et al (1991) have demonstrated that good and poor learners engage in different strategies in solving electrical circuit problems. Good learners were superior in the planning and the control of variables. They also generated more hypotheses, of which a greater proportion was correct, and they were better at data management. Studying transfer in causal reasoning, Kuhn et al (1992) pretested subjects in each of two domains, and subsequently provided experience in one domain, measured performance in that domain, and at intervals measured performance in the second domain. They found that learning occurred in both domains, and attributed the findings to the use of appropriate strategies and to the growth of metacognitive awareness.

Other intervention studies have also demonstrated facilitation in scientific thinking. Linn & Songer (1993) measured student ideas of scientific explanations, parsimony, and relevance of science to everyday problems, and found that a preliminary course emphasizing the integration of science concepts with everyday thinking improved learning. Similarly, Shayer & Adey (1993) obtained facilitation, even three years after the intervention, when they provided conceptual experience with the use of variables, cognitive conflict, metacognition, and knowledge of strategies. Schauble et al (1994) found that teachers who had been trained in scientific reasoning, and later gave sixth graders a three-week course on experimentation, produced significant improvement in student understanding of experimentation. The authors concluded that without curriculum change, there is substantial opportunity for teachers to provide instruction about experimentation. Carey (1986) and Carey et al (1989) found students' views of science as a passive and accurate copy of the world changed toward a more constructivist view when students were provided with appropriate instruction.

Another intervention study (Rosebery et al 1992), conducted in a minority classroom with students generally naive to science, used a collaborative procedure in which science was viewed as one type of literacy and as part of an interdisciplinary instructional effort. After studying hypotheses involving water taste and purity, students demonstrated significant improvement with respect to scientific thinking. Lock (1990) showed that low-ability students could profit from training in planning and interpretation. In a relatively rare longitudinal study, first and second grade children were instructed in physics and biology concepts and interviewed periodically from first through twelfth grade (Novak & Musonda 1991). Subjects who received training provided more valid conceptions and fewer misconceptions than did controls, with the difference persisting through twelfth grade.
Informal Reasoning Skills

Informal reasoning is a loose term referring generally to the probabilistic reasoning taking place in everyday situations. Such reasoning is characteristically goal-related and has the argument as its core structure. Goals include justifying one’s own position and/or attacking another person’s, making a decision, persuading others, or resolving a conflict. The argument usually takes the form of an enthymeme, that is, a claim (conclusion) supported by a reason (premise). One premise of the argument is thus not made explicit, the missing premise in Toulmin’s (1958) terms being the warrant of the argument (cf Voss et al 1991 for a more extensive discussion of informal reasoning). Research in this area has focused on skills in the use of argumentation, which are relatively poor in the general population.

Justifying One’s Position  In studies of informal reasoning, individuals are often asked to generate an answer to a question, to justify the answer, and to state counterarguments (Kuhn 1991, Means & Voss 1994). Or, individuals may be given arguments to evaluate. Results of such studies indicate that 1. individuals have relatively poor argumentation skills (Kuhn 1991, Means & Voss 1994); 2. informal reasoning skills are related to intellectual ability level (Perkins 1985) and to educational level, which may be interpreted as ability level (Baron et al 1993, Kuhn 1991, Voss et al 1986); 3. informal reasoning skill sometimes improves with age although the results may often be attributed to knowledge differences (Kuhn 1991, Means & Voss 1994); 4. individuals, while sometimes providing good evidence, also provide pseudoevidence, essentially a narrative of how, for example, a given person may have failed in school, rather than stating a causal analysis (Kuhn 1991), and 5. students apparently do not develop informal reasoning skill in school (Perkins 1985). Voss & Means 1991 have suggested ways to provide such instruction and practice in schools.

Decision Processes  A common normative assumption is that rationality includes examining both sides of a claim (Baron 1988). However, individuals usually provide more justification for their own side than for the other (Baron et al 1993, Perkins 1985). This deficiency is possibly the result of an inadequate search (Baron 1988). Perkins et al (1983) suggest that individuals often only search to the point of providing an answer that makes sense, rather than providing a critical epistemology, which involves more search and evaluation, what Baron (1988) terms fairness. Further, Roussey & Gombert (1994) found that children had difficulty constructing a two-sided argument unless the children were good writers and were placed in a dyad situation.
PERSUASION  From a developmental perspective, preschool children use persuasive arguments when trying to convince mother or when buying or sharing a toy. They use sanctions, requests, and assertions as persuasive mechanisms. Older children use more positive sanctions to persuade while younger children rely more on assertions per se (Weiss & Sachs 1991).

CONFLICT RESOLUTION  Stein & Miller (1991) found that children as young as five understand the nature of conflict, with such disputes arising typically over the possession of objects or through social behavior. Stein & Miller (1993a,b) also concluded that children as young as second graders are able to provide support for their arguments and can provide counterarguments. Slomkowski & Killen (1992) have shown that children as young as four provide different justifications in relation to context: Children provide personal justifications if asked about transgressions involving friends, but they use moral or social-conventional justifications for transgressions involving non-friends. Hofer & Pikowsky (1993) studied mother-daughter conflict and found that the goals and arguments of the conflict differed. Mothers desired to control the argument and daughters desired independence, trying to weaken their mothers' position. Stein et al (1994) studied argumentation skill of adolescents in a negotiating situation in which compromise was sought. They found that initial knowledge had little to do with outcome; social factors occurring during the negotiation played a critical role.

LANGUAGE AND ARGUMENTATION  In general, older children are better at writing argumentative text than are younger children (Coirier & Golder 1993, Golder 1992). In a study of children aged 7–16, the youngest children did not express a position, slightly older children took a position without justifying it, still older children developed minimal arguments, later providing elaborated arguments, and counterargument occurred typically at about age 14 (Coirier & Golder 1993). Golder (1993) also found that personal involvement with the topic is related to better argument generation. Zammuner (1987) had subjects write about their position on abortion and found that the construction of argumentative text was more elaborated for individuals favoring abortion. The result was attributed to the anti-abortion sociocultural atmosphere of Italy, where the study took place.

TEACHING CRITICAL THINKING SKILLS  Common to a number of critical thinking programs are the skills of defining problems, evaluating information, and generating and evaluating alternatives (Adams 1989, Idol et al 1991). Some researchers suggest that students need a critical-thinking disposition (Halpern 1989, Norris 1989), that is, the willingness to engage in activities such as planning, learning from mistakes, persistence, and open-mindedness. Simply
having a student serve as task designer, strategist, monitor, or challenger in
group problem solving on everyday problems has yielded positive effects, with
retention found up to 8 weeks after training (Riesenmy et al 1991). Costa (1991)
provides a summary of programs used successfully for the teaching of higher
mental skills.

Verbal Skills

LEARNING FROM TEXT  Kintsch (1986) distinguished between remembering
text contents and learning from text, that is, recalling text contents vs using
the contents for inference generation and problem solving. Although Kintsch
(1994) reported that more coherent texts produce better recall than do less
coherent texts, the latter may produce better learning because individuals need
to generate inferences to understand the text, thereby producing integration
of a priori knowledge and information in the text. Similarly, Voss & Silfies
(1994) showed that when using an expanded history text in which causal
statements were “unpacked,” recall performance was correlated significantly
with reading comprehension scores but not with history knowledge; however,
for an unexpanded text, recall performance was related to prior history knowl­
edge but not to reading comprehension. The authors concluded that in the
unpacked text individuals use their prior knowledge to fill in gaps, whereas the
expanded text reduces the role of knowledge and makes reading comprehension
more important. In another study, a mismatch between a text outline and the text
organization itself resulted in better performance on inference tasks than when
the text and outline agreed (Mannes & Kintsch 1987). Roller (1990) concluded
that text structure is of greatest importance when the subject matter is somewhat
unfamiliar.

Work on learning from text has indicated that generating explanations to
questions about a text facilitates learning (Pressley et al 1992). Other research
has examined the role of prior knowledge (cf Alexander & Judy 1988) and the
other than narratives have also been used, including expository text (e.g.
Varnhagen 1991) as well as editorials and literature (cf Britton & Graesser
1994). Causal narrative structure has been found to be significantly related to

WRITING  Bereiter & Scardamalia (1987) have suggested that less-advanced
writers view writing as a knowledge-telling exercise, while more-advanced
writers see writing as knowledge transforming. The latter also revise at a more
global level than do the former (cf Hayes 1990). Methods to improve the skill
of less-advanced writers include providing students with a clear under-
standing of the task (Nelson & Hayes 1988), although this procedure can only be effective when the younger students have other requisite skills. Thus, Wright & Rosenberg (1993) found that fourth graders could not recognize or produce coherent text, while students were able to by eighth grade. Experienced writers are better at recognizing potential obstacles for a reader and at taking a reader’s perspective (Schriver 1990). Also, use of a word processor may increase productivity, but writing via a computer tends to produce more grammatical errors (D’Odorico & Zammuner 1993), engenders less planning before and during writing, and tends to inhibit a spatial sense of text organization (Haas & Hayes 1986).

**QUESTIONING** McKeown et al (1993) found that a procedure they termed “Questioning the author,” which involves students asking questions of the text, facilitated student learning. Singer (1990) discussed the various cognitive components involved in question answering, especially in relation to inference generation, and Graesser & Person (1994) found that individuals asked more questions in a tutoring context than in the classroom.

**SOCIAL CONTEXTS OF INTELLECTUAL SKILL ACQUISITION**

One of the most profound movements in the study of intellectual skill acquisition has been the study of how social and cultural factors are related to skill acquisition. Two related lines of such work are described below: One involves collaborative learning and the other is concerned with situated learning and apprenticeship.

**Collaborative Learning**

Brown & Palincsar (1989) reviewed the literature on collaborative learning and its relation to acquisition. A point emphasized is that collaborative learning success is related to the generation of explanation and elaboration, processes that trigger the need to reflect and the need to deal with conflict. They also note that change “is not the result of social qua social, motivational qua motivational, or even conflict qua conflict, it is the result of certain social settings that force the elaboration and justification of various positions” (p. 408). Another analysis of cooperative learning (Slavin 1987) integrated motivational and social-developmental interpretations. Slavin suggested that a social context can set a motivational context so that individuals will provide more explanations and elaborations.

At the empirical level, Brown et al (1993) observed conceptual change in both teachers and students in a classroom situation under conditions of distributed expertise (in which different students researched particular subtopics of a
domain and reported their findings). Four factors related to classroom learning were noted: the presence of guided discovery; the student serving as teacher, researcher, and monitor of progress; active student inquiry; and thinking as basic literacy. These components, Brown et al argued, established a community of learners.

Orsolini & Pontecorvo (1992) found that with children aged 5 and 6, classroom discussion about a story facilitates argumentation, with children challenging not the facts of the story but the claims of other students. The disputes produced positive outcomes, such as learning to justify and stating explanations and counterarguments. Pontecorvo & Girardet (1994) also found that 9-year-old children in a non-teacher guided discussion sometimes arrived at a higher level of cognitive activity than they did when teachers were present. Gilly (1991), citing a study by Are, indicated that children aged 7 and 8 rarely questioned how to solve a problem with no possible solution when in the classroom, but while working with an adult or a peer, students produced more questioning and rejection of the problem.

In a review of peer interaction effects in the context of small groups, Webb (1989) concluded that group activity yielded high levels of elaboration and explanation as well as better achievement. The relative homogeneity or heterogeneity of the group was also important, as was personality, with extroverts obtaining more attention than did introverts.

Blaye et al (1991) found that pairs of 11-year-olds working on a computer-based problem solving task performed better than did individuals working alone, both with respect to original learning and when working alone on a transfer task (cf Azmitia 1988). Clements & Gullo (1984) also found positive dyad effects in the development of planning strategies, while Perlmutter et al (1989) reported that with children aged 4–11, the older children benefitted from peer interaction more than did younger children, especially for complex tasks. Juel (1991) found that in a cross-age tutoring procedure, young at-risk children improved in reading skill when tutored by college athletes, who also benefitted from the program.

Situated Learning and Apprenticeship

The concept of situated learning has emphasized the cultural context in which intellectual skill acquisition takes place. The concept generally holds that skill acquisition and the sociocultural context cannot be separated (Brown et al 1989, Lave 1989, Lave & Wenger 1991). Activity in turn is cued by the situation, a view that leads to a distinct view of transfer (Säljö 1991, Säljö & Wyndhamn 1990). Lave (1989) argued that although transfer traditionally focuses on learning of a skill in one context and applying it to another context, such transfer is difficult to obtain. The situated learning model considers
transfer to have occurred when a new situation cues or triggers a response. Although the situated learning concept contains a sociocultural component, the strong version of the position is akin to behaviorism in that it assumes that environmental stimuli produce behavior. The situated learning model was in part derived from findings suggesting that theories built upon mental structures (e.g. Piaget's) had difficulty in dealing with performance variability (Guberman & Greenfield 1991). Guberman & Greenfield further noted that the situational view needed to be integrated with views about what was going on in the heads of individuals. This integrative process has been the subject of recent research. Cole (1989), for example, pointed out the importance of culture in the development of literacy. Guberman & Greenfield (1991) also argued that goal-setting is a function of a person's interaction with the social context, and an individual's mental representation then constitutes the mental structure of the goal in the social context. These authors cited Cheng & Holyoak's (1985) work on pragmatic schema as an example of such integration of situational and representational components. A similar line of research showed that knowledge of procedure acquired in a particular context leads to a mental representation consisting of an abstraction of the procedure in that context (Hatano 1988).

Apprenticeship has been defined as the teaching of crafts by means of practical activity in one-to-one relationship with an expert of the field (Gardner 1991, Hamilton 1990), and as such constitutes learning in a particular situated context. The apprenticeship process consists of observation, coaching, and practice (Lave & Wenger 1991), with the learner building a conceptual model of the task. The model becomes more developed during the guidance and practice phases as the learner integrates feedback from the master. Apprenticeship thus takes place in the context of particular learning environments. Rogoff (1990) stressed the importance of social interaction in apprenticeship learning, but Radziszewska & Rogoff (1988, 1991) found that only particular forms of peer interaction yield instructional benefits. Not only must one partner be more skilled than the other, but the more-skilled partner must also supply explanations for particular strategies, and also allow the less-skilled partner to participate in decisions. Thus, without both guidance and participation, the less-skilled partner does not benefit from the interaction. Further, the studies suggest that the benefit of apprenticeship might be limited by age. Even when given guidance and the chance to participate, the youngest students that were studied, aged 4–5, seemed unable to benefit from interaction with a skilled partner.

Establishing appropriate learning environments has also been addressed by developing computer-based contexts to facilitate learning. Examples of such work include the development of tutoring systems in economics (Achtenhagen 1991, Shute & Glaser 1991), medical diagnosis (Clancey 1987), and computer...
programming (Harel & Papert 1990). De Corte (1990) has developed a learning environment for mathematics designed to foster the development of successful problem solving.

SOME SIGNIFICANT ISSUES

Individual Differences

With the exception of the study of prior knowledge, little research has been carried out on individual differences in intellectual skill acquisition. However, research on individual differences will likely increase, as suggested by recent work on prior knowledge, motivation, interest, and ability level.

Studies have generally indicated that greater knowledge of a given subject matter domain facilitates the acquisition of new domain-related information. However, research (e.g. Reif & Allen 1992) has indicated that a person’s general world knowledge and his or her beliefs, attitudes, and values are also important. Tishman et al (1993) have suggested that individuals in given situations have predisposing tendencies to act in particular ways, which in turn can influence intellectual skill acquisition. What constitutes a disposition, however, is not clear. What might be expected in the future is that the relation of acquisition and prior knowledge will be studied with a more precise measurement of prior knowledge as well as a broadening definition of what constitutes relevant prior knowledge and tendencies to use it in particular ways.

Research on the roles of motivation and emotion in acquiring intellectual skills has increased. Dweck & Leggett (1988), for example, have shown that a student’s goal orientation (in terms of whether to please via performance or to learn competence), the student’s own perceived ability, and the student’s view of intelligence (as fixed or malleable) are related to intellectual skill acquisition. Also, Boekaerts (1993) has shown that how anger is controlled, rather than anger per se, is related to school performance. The related issue of how interest facilitates acquisition of intellectual skill has also been studied (see Renninger et al 1992). Ability level is one of the most important individual differences that requires study (Perkins 1985, Means & Voss 1994). Although much has been written about intelligence, two key questions remain unanswered: 1. What is the basis of ability-level differences? and perhaps even more importantly, 2. To what extent can intellectual skill acquisition for low ability-level individuals really be facilitated?

General versus Specific Skills

Research indicates that both general and specific skills exist, as found, for example, in the use of general heuristics and metacognitive skills on the one
hand and specific domain-related skills on the other. The potential controversy emerges, however, in relation to how these skills are acquired and especially the extent to which they transfer. Detterman (1993) holds an extreme position, arguing that transfer effects are primarily found only when subjects are told how and what to transfer (cf Ceci & Ruiz 1993). Perkins & Salomon (1989), however, in reviewing the history of the controversy, noted that there was an early adherence to the general skills position, followed by adherence to the specific skills position, but that currently there is a return to a more general skills position, with transfer occurring in relation to the use of general heuristics and metacognitive strategies, such as those used by Brown & Palinscar (1989).

Studies have demonstrated transfer of relatively specific skills. Brown & Kane (1988), for example, using learning-to-learn and example-based learning paradigms, found that children aged 3–5 could transfer in both paradigms: The children responded not to surface but to underlying features. Brown & Kane also found that reflection about the problem facilitated transfer and that children who explained their learning transferred more than when information was provided by the experimenter. Lehman et al (1988) demonstrated that training in psychology, medicine, and law yielded positive transfer with respect to conditional reasoning while chemistry training did not. Psychology and medical students also showed significant gains in statistical-methodological reasoning while law and chemistry students did not. Fong et al (1986) showed that training in statistics led to a significant improvement in everyday thinking. Studies in computer science have also demonstrated positive transfer effects (Black et al 1988, Klahr & Carver 1988, Reed & Palumbo 1992). In some cases, however, transfer has been difficult to obtain. For example, Bassok & Holyoak (1993) found a lack of transfer across isomorphic word problems in physics and algebra, while Leshowitz (1989) observed difficulty in transferring what is learned in social science courses.

The most reasonable position seems to be that transfer of specific skills is difficult to obtain, but it can be facilitated by training that includes elaboration and explanation as well as self-monitoring metacognitive processes. The use of general heuristics, however they are acquired, seems to occur to the extent that individuals had training in their use and that a particular situation arose that activated the heuristics. This topic, however, has been a long-standing matter of controversy, and the future will likely produce more evidence indicating that transfer “depends on....” We also agree with Sternberg (1989), who has argued that the general-specific distinction is overstated and that the research requires consideration of factors such as context and personality.
The Sociocultural Revolution and Active Processing

THE SOCIOCULTURAL REVOLUTION Although psychology has been experiencing a cognitive revolution since the 1950s, the most recent decade has produced what may be termed a sociocultural revolution. Although intellectual skill acquisition has traditionally been and still is regarded as primarily the responsibility of formal education, research in the last decade has aptly demonstrated that considerable skill in intellectual functioning can be and often is acquired outside of the classroom. Furthermore, such acquisition takes place because the sociocultural context creates the need for individuals to acquire such skills (e.g. Lave 1989, Nunes et al. 1993). This relation of sociocultural context and an individual’s intellectual development suggests, moreover, that such development is based on socially derived goals involving motivation and emotion. Indeed, Bruner (1990) has emphasized such factors in his plea for the study of “folk psychology.” Along with greater study of out-of-school learning there has been increasing concern regarding the relation of such learning to the classroom. Thus, one question is that of two-directional transfer: To what extent can in-school knowledge be used to facilitate out-of-school learning, and to what extent should out-of-school learning be built upon in the classroom?

Another aspect of the sociocultural revolution is the general finding of positive results in the acquisition of intellectual skills through social interaction. Such results tend to change the view of learning from the strong emphasis placed on individual learning to a more collective form of systemic learning.

ACTIVE PROCESSING While in recent years the importance of the sociocultural influence upon learning has been increasingly recognized, strong evidence has also underscored the individual as an active learner. Some time ago the idea that the individual is an active and not a passive learner became a cliché. Nevertheless, recent evidence indicates that intellectual skill acquisition is facilitated when individuals generate their own solutions to problems, explain and elaborate upon their solutions, and employ metacognitive skills. The sociocultural influence can act to produce more processing, in terms of elaboration and justification, than may otherwise occur (e.g. Brown & Palincsar 1989). This outcome has been demonstrated in many domains, and future research will likely produce a better understanding of how such learning occurs. In sum, recent studies of the acquisition of intellectual skills have generated research and theory about the nature of learning these skills and how they may be used (cf. Bruer 1993). At the same time, the work has produced the need for theory development, and has reinforced Jenkins’s (1979) point that because learning seems to depend on the context, the nature of materials, the task, and the ability, knowledge, motivation, and interest of individuals, the idea of arriving at invariance seems quite remote.
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